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QUESTIONS AND PROBLEMS

IN

ELEMENTARY PHYSICS,

CONTAINING

NUMEROUS PRACTICAL EXAMPLES AND EXERCISES FOR USE OF PUPILS IN HIGH SCHOOLS AND ACADEMIES.

BY

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PREFACE.

Every teacher appreciates the value of a comprehensive series of questions and problems in Elementary Science. Next to the experiment, they are the only practical means of testing the student's accuracy, and, at the same time, of extending his knowledge. In the minds of some there may be a doubt as to the importance of questions; there can be none in regard to problems, for these are as indispensable in Physics as they are in Arithmetic.

This volume claims comprehensiveness so far as concerns instruction in the Elements of Natural Philosophy or Physics in the lowest, or next to the lowest, grade of our High Schools. It may be used as an auxiliary to any text book. Most of the problems require only so much knowledge of Mathematics as every young person is supposed to possess on entering the High School. Solutions of problems have occasionally been inserted in the text. The metric system has, throughout the entire volume, received the attention due to its importance.

The answers to the problems will shortly be published, and may be obtained by teachers upon application to the publishers.

Cleveland, Ohio, April, 1877.

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REMARKS.

Each example or question has its own number. At the close of a section a few numbers are left blank for any example or question that the student may wish to add.

For practical purposes as well as for the sake of convenience, fractions may be considered as units, when they differ from a unit by only a minute quantity; thus, 172.788 may, in nearly all cases, be taken = 172.8.

The sign of multiplication adopted in the problems is the period (.), because the usual sign (×) is, in writing, easily confounded with x. Thus, $2 . 3 = 6$.

Unless stated otherwise, the term velocity means velocity *per second* of mean solar time.

All objects are considered as moving without friction or resistance. Any exception to this is distinctly indicated. In solving problems, the young learner is cautioned against writing his answer without adding its denomination.

Questions or Problems marked "S. K." (South Kensington) have been selected from "Examination Papers for Science Schools and Classes, London." Those marked "T." are Prof. Tyndall's. "M." refers to Magnus, Elem. Mechanics; "B." to Burbach, Physikal. Aufgaben; "To." to Todhunter, Mechanics for Beginners; "A." to Atkinson, Prob. and Examples in Physics; "C. & M." to Chevallier et Müntz, Problèmes de Physique; "D." to Day, Numerical Examples in Heat.

MATHEMATICAL DATA.

π = ratio of circumference of circle to diameter = 3.1416.
Circumference of a circle (d=diameter) = πd.
Area of circle = πr^2 = square of diam. × 0.7854.
Surface of a sphere = square of diam. × 3.1416.
Cap. or vol. of a sphere = $\frac{4 \pi r^3}{3}$ = cube of diam. × 0.5236.
Cap. or vol. of cylinder = $\pi r^2 l$ = area of base × by height.
Area of retangle, square, rhombus, rhomboid = base × height.

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INTRODUCTION.

(METRIC SYSTEM.)

(*See Table in Appendix.*)

(A nickel five cent piece weighs five grams., and is two centimeters in diameter.)

1. How many centimeters in a meter? In a decimeter? In five decimeters?

2. How many millimeters in a centimeter? In a decimeter? In a meter?

3. How many centimeters in five meters? In a decameter?

4. How many millimeters in three meters? In two decameters?

5. What fraction of a meter is ten centimeters? Ten millimeters? One decimeter?

6. What fraction of a meter is the sum of two decimeters, fifteen centimeters and fifty millimeters?

7. What fraction of a centimeter is a millimeter? Four millimeters?

8. What fraction of a kilometer is 125 meters? 0.5 meter?

9. Distinguish between a decameter and a decimeter. Express the difference in centimeters.

10. The velocity of a man walking rapidly is 1.8 meters, nearly. Convert this into feet.

(Take 1 meter = 39.37 inches, then 1.8 m. = 1.8 • (39.37) = 70.866 inch = 5 ft. 10.866 inch, answer.)

11. The velocity of a horse galloping is from 4 to 5 meters. Express this in feet.

12. The velocity of a railway train is from 8 to 18 meters. Express this in feet.

13. The velocity of steam vessels is from 3 to 7 meters. Express this in feet.

14. The velocity of a rifle ball is 500 meters, nearly. Express this in feet.

15. The velocity of a 24-pound ball is 800 meters, nearly. Express this in feet.

16. The velocity of sound is 333 meters, nearly. Reduce this to feet.

17. Reduce to inches the diameter of a nickel five cent piece.

---

18. How many centimeters in a yard?

(Take 1 ft. = 0.3048 m., then 3 ft. (= 1 yd.) = 3 • (0.3048) m. = 0.9144 meter = 91.44 centimeters.)

19. How many meters in a mile?

20. Reduce an inch to centimeters.

21. Assuming the height of the atmosphere to be 26,200 feet, what is it in kilometers?

22. The mercury in a barometer stands 30 inches; how many millimeters is this?

23. Reduce 25 pounds (avoir.) to kilograms.

(Take 1 pd. = 0.4536 kilo., then 25 pds. = 25 • (0.4536) = 11.34 kilograms.)

24. Reduce 1 ounce (avoir.) to grams.

25. A cubic foot of water weighs 62½ pounds, nearly. Reduce this to kilograms.

26. The weight of one hundred cubic inches of air is 31 grains, nearly. Reduce this to grams.

27. A cubic foot of brickwork weighs about 1 cwt. Reduce this to kilograms.

28. The pressure of air is nearly 15 pounds to the square inch. Reduce this to kilograms.

29. The weight of a traction engine is 6 tons. Reduce this to kilograms.

30. How many pints in 18,200 c. c. (cubic centim.)?

31. What is the unit of length in the Metric system, and what its approximate value in the English system?

32. How is the meter divided? Give the names of the principal multiple and sub-multiple divisions.

33. What is meant by a liter? How many liters in a cubic meter?

34. Give the equivalent of a liter in English cubic inches.

35. How many cubic centimeters (c. c.) in a cube, each edge of which is 0.5 meter long?

36. How many liters in the same?

37. In 10.5 liters how many c. c.?

38. Find the area (in sq. cent.) of a nickel five cent piece.

39. State what is meant by a meter.

40. State what is meant by a gram.

MOTION.

UNIFORM MOTION.

43. What is motion? What is uniform motion?

44. What is meant by velocity? By acceleration?

45. A body passes over 840 feet in two minutes. Required its velocity.

46. A point in the circumference of a grindstone is 1 foot distant from the centre; it revolves 5 times in 21 seconds; find the velocity of the point.

(The diameter $= 2 \cdot 1$ ft. $= 2$ ft, and the circumference of the grindstone $= 2 \cdot 1\ (3.1416) = 6.2832$ ft. If the point revolves 5 times in 21 seconds, it passes over a space of $5 \cdot (6.2832)$ ft. $= 31.416$ ft. in 21 seconds, and over $\frac{31.416}{21} = 1.496$ ft. per second, answer.)

47. A carrier pigeon traveled 200 miles in 4 hours, 4 min., $26\frac{2}{3}$ sec. Find its velocity.

48. The length of the minute-hand of a watch is 21 millimeters. Required the velocity of its point.

49. Assuming the length of the equator to be 24000 miles, what is the velocity of any point on the equator?

50. What diameter must a wheel have in order to make 90 revolutions a minute, and that the velocity of any point at its circumference may be 9 meters? (Take $\pi = 3.$)?

51. How many revolutions must each of the driving wheels of a locomotive make in an hour, if the diameter of each is 6 ft., and if the velocity of the train is 54 ft. (Take $\pi = 3.$)?

52. Distinguish between motion of translation, rotation and vibration.

53. A body passes over 100 feet in 10 seconds, while another body passes over 20 feet in $\frac{5}{4}$ seconds. Find the ratios of their velocities.

54. What is the average velocity of the piston in a steam cylinder if it makes 40 strokes per minute, each 1 meter long?

UNIFORMLY ACCELERATED AND RETARDED MOTION.

55. What is meant by variable motion; by uniformly accelerated motion, and retarded motion?

56. What is meant by periodic or recurring motion?

57. The acceleration of a moving body is 6 feet per second. Explain the meaning of this.

58. A body starting from rest has been moving for 6 minutes, and has acquired a velocity of 30 miles an hour. Find its acceleration (c) per second.

(Velocity $= \frac{30 \cdot 5280}{60 \cdot 60} = 44$ ft. per second. Now $v = t\,c$, that is, $44 = 360$ sec. $\cdot\ c$., hence $c = \frac{11}{90}$ ft.)

59. In what time will a body, moving from rest with an acceleration of 25 ft. per second, acquire a velocity of 500 ft. per second?

60. What space will a body pass over in 6 seconds, if it moves with an acceleration of 80 yards per minute?

(Its acceleration per second $= \frac{80}{60}$ yds. $= 4$ ft. Its velocity during the last second $= 24$ ft.; hence its mean velocity per second $= \frac{4+24}{2} = 14$ ft., and in 6 seconds the space passed over $= 6 \cdot 14 = 84$ ft.)

61. What space will a body describe in 10 seconds if moving with an acceleration of 5 meters per second?

62. With what velocity per second must a body start if its velocity be retarded 6 ft. every second and if it comes to rest in 6 seconds?

63. With what velocity will a body move after 5 seconds if it started from rest with an acceleration of 12 ft. per second?

64. What are the chief impediments to motion?

FIRST LAW OF MOTION.

66. State the first law of motion.

67. How does a body tend to move when set in motion?

68. A stone is tied to a string and whirled round; if the stone free itself from the string, in what direction will it move?

69. What is meant by inertia?

70. Mention three facts that serve to verify Newton's first law of motion.

71. Why can we drive the head of a hammer by striking the end of the handle?

72. Explain why a "running jump" is longer than a standing one?

SECOND LAW OF MOTION.

73. State the second law of motion.

74. What is the direction of a stone dropped from the masthead of a vessel in motion?

75. If a person is walking in a straight line, in what direction must he throw a ball upward that it may return into his hand?

76. If a ball be held out of the window of a railway carriage in rapid motion, and then be dropped, in what direction will it seem to fall, *a*, to a passenger? *b*, to an observer on the ground? *c*, in what direction will it really fall? (Illustrate by a drawing.)

77. What is meant by the parallelogram of motion, or of forces?

78. What is meant by resultant motion?

79. Given a fixed point a on a vessel, and the direction in which the vessel moves. A ball is assumed to be thrown from a to a fixed point on the shore. Show by a diagram the direction of the path of the ball (gravity neglected).

80. A column of smoke tends to rise vertically from a chimney, with a velocity equal to c, but the prevailing wind is horizontal, and has a velocity of $2c$. What is the path of the smoke.

81. A man crosses a river in a row-boat at right angles to the current. The current is assumed to be 4 miles an hour, the velocity imparted to the boat by the oars $= 3$ miles an hour. Draw a parallelogram, and give the length of the resultant. ($\sqrt{4^2+3^2} = 5$ miles.)

82. A body while moving vertically downward, with a uniform velocity of 10 feet, is urged horizontally with an acceleration of 5 feet. Find its distance from the starting point after 2 seconds.

83. A body tends to move horizontally with a uniform velocity of 12 feet, and also vertically downward with a uniform velocity of 8 feet. Determine its position after 3 seconds.

84. If two forces of 5 and 7 units act on a point in directions at right angles to each other, show by a diagram the direction in which the point begins to move.

85. A balloon is carried along by a current of air moving from east to west, at the rate of 60 miles an hour, having no motions of its own through the air, and a pith ball is dropped from the balloon. What sort of a path will it appear to describe as seen by a man in the balloon? What will be its actual path? (Illustrate by a diagram.)

86. A ball, having a velocity of 1800 feet, strikes the side of a vessel in motion. The vessel is 50 feet wide; the place at the other side of the vessel, where the ball passes out, lies 4 inches farther to the rear than the place where the ball struck first. Find the velocity of the vessel (retardation of the ball neglected).

87. A ship is 1560 meters from the shore, and travels parallel to the shore with a speed of 10 meters. A cannon ball is fired with the assumed velocity of 780 meters from the ship against the shore. The ship at this instant is supposed to cease moving. How far in the direction of the previous motion of the ship will the ball strike the shore?

88. A body is subjected to two forces, of 90 and 112 pounds respectively, acting upon it at a right angle. Find the resultant force by which the body is propelled.

89. A steamer moves due north with a certain velocity, the wind blowing from the west with the same velocity. In what direction will a streamer on the vessel point? (Illustrate by a diagram.)

90. A steamer is going north with a velocity of 12 miles an hour; the wind is blowing from the west with a velocity of 3 miles per hour. What will be the direction of a streamer on the masthead of the vessel? (Illustrate by a diagram.)

91. A vessel is sailing northeast with a certain velocity; the wind is blowing from the south-southwest at the same rate of speed. Find the direction of a streamer on the masthead of the vessel. (Illustrate by a diagram.)

THIRD LAW OF MOTION.

92. State the third law of motion, and show how it holds in case of a stone falling to the earth.

93. What is meant by tension? How does it illustrate the third law of motion? M.

94. Show the application of the third law of motion in hammering a nail into the wall; in the fall of a heavy body to the earth; in the driving of piles into the ground. M.

95. If a shot weighing 20 pounds leave a gun weighing 3 tons with a velocity of 1200 feet, find the velocity of the recoil of the gun.

96. Explain the terms "force," "weight" and "pressure.'

97. Four men of equal strength are in a boat on a lake. They all have oars, but only one of them is rowing, giving' the boat a velocity of 2 miles per hour. What would be the velocity of the boat if the other three men helped rowing?

98. Two spring balances are fastened together at their fixed ends, and are then pulled horizontally, in opposite directions, by two men, one at each end. With what force will each pull?

99. Two spring balances are so connected with each other that the fixed end of the one is fastened to the movable end of the other; two persons then pull at opposite ends, in a horizontal direction. What is the effect of the pull?

100. The pair of spring balances of the preceding example are now held vertical, the movable end being below. What do the balances indicate when the free end is pulled down?

101. A man standing on shore pulls in a rope, part of which is on a vessel at some distance from the shore. If, now, a man on the vessel also begins to pull rope into the vessel, will the vessel then move faster toward the shore than before?

102. Suppose that the man on shore had been pulling with all his strength when the other person commenced to pull rope into the vessel, would the vessel then move faster toward the shore than before?

GRAVITY.

107. Mention the points that must be specified in order that a force may be considered as known.

108. What is meant by universal gravitation, and why is it called universal?

109. What is Gravity?

110. What is the direction of gravity, and how may this be illustrated?

FALLING BODIES.

(Unless otherwise indicated, take $g = 32$ ft., or $= 10$ meters.)

FORMULÆ.

(1) $v = t\,g$

(2) $v = \sqrt{2\,g\,s}$

(3) $s = \frac{1}{2}\,g\,t^2$

(4) $s = \frac{v^2}{2\,g}$

(5) $t = \frac{\sqrt{2\,s}}{\sqrt{g}}$

111. Give formulæ for the falling bodies.

To find v:—

112. A body falls freely for five seconds; what is its velocity at the end of the time?

($5 \cdot 32$ ft. $= 160$ ft. Or $5 \cdot 10$ meters $= 50$ meters.)

113. What was its velocity at the end of the fourth second?

114. What was its velocity at the end of $3\frac{1}{2}$ seconds of its fall?

115. A body falls freely for one-fourth of a second, what is its velocity per second at the end of that time.

116. Suppose that a body falls under gravity for 10 seconds, with an initial velocity of 20 feet per second, what will be its velocity per second at the end of that time?

(10 . 32 = 320 feet by gravity. Init. velocity = 20 feet per second, hence 320+20=340 feet vel. per second, answer.)

117. What will be its velocity per second at the end of the first two and a half seconds of its fall?

(Its velocity by gravity will be $2\frac{1}{2} \cdot 32 = 80$ ft. per second. Its init. velocity = 20 ft. per second; hence, 80 + 20 = 100 ft. vel. per second, answer.)

118. A body falls freely for six seconds; at the beginning of the third second of its fall it receives a blow which imparts to it an additional velocity of 10 feet per second. What velocity per second will it have at the end of the sixth second?

119. A man is standing on a platform which descends with a uniform acceleration of 5 feet per second; after having descended for 2 seconds he drops a ball; what will be the velocity of the ball after two more seconds? (S. K.)

Answer: 74 feet velocity per second.

120. After a balloon had been ascending vertically at a uniform rate for $4\frac{1}{2}$ seconds, a stone let fall from it reached the ground in 7 seconds after the balloon started. Find the velocity of the balloon, and the height from which the stone was dropped. (g = 32, 2.) (S. K.)

121. A body is thrown vertically downward with a velocity of 20 meters a second; what will be its velocity at the end of 5 seconds?

122. A freely falling stone acquires what velocity in $5\frac{1}{2}$ seconds? Suppose gravity at the end of this time to cease acting, what will be the velocity of the stone at the end of the next half second?

Find space passed over:

124. A stone dropped from the top of a tower struck the ground in 4 seconds. How high is the tower?

($s = \frac{1}{2}\ g \cdot t^2 = 16 \cdot 4^2 = 256$ ft.)

125. What space did the stone describe in the last second?

(Space described in 4 sec. $= 256$; space described in 3 sec. $= (16 \text{ ft.} \cdot 3^2) = 144$ ft. Now, $256 - 144 = 112$ ft., answer.)

126. What space did it pass over in the first $2\frac{1}{2}$ seconds of its fall?

($s = 16 \text{ ft.} \cdot (2\frac{1}{2})^2 = (16 \cdot \frac{25}{4}) = 100$ ft., answer.)

127. A body was falling freely for one-half sec. Through what height did it fall?

128. How deep is a well with 20 feet of water, into which a stone is dropped which reaches the surface of the water in $1\frac{1}{2}$ seconds?

129. A body falls freely during 10 seconds; suppose gravity to cease acting upon it at the end of the seventh second, what is the entire height of the fall of the body?

130. Two balls are dropped into a mine, one of them 3 seconds before the other. What space are they apart 5 seconds after the first was let fall?

131. If a body, having fallen 3 seconds, breaks a pane of glass, and thereby loses one-third of its velocity, find the entire space passed over at the end of the fourth second.

132. A balloon rises uniformly with a velocity of 10 feet per second, when a man drops a stone, which reaches the ground in 3 seconds after it was dropped. Find the height of the balloon, *first*, when the stone was dropped; *secondly*, when the stone reached the ground.

133. At the instant of falling vertically a body is impelled by a force which causes it to move (vertically) three feet per

second; how far is the body from the starting point after two seconds?

(Space described under gravity $= (16 \cdot 2^2) = 64$ ft. Space described by virtue of the impulse $= 3 \cdot 2 = 6$ ft.; $64 + 6 = 70$ ft.)

134. A ball is dropped from the top of the mast of a ship, which is sailing at the rate of 18 miles an hour. If the mast be 64 feet high, how far will the ship have sailed during the passage of the ball.

135. Through what space must a body fall vertically to acquire a velocity of 96 feet per second? To acquire a velocity of 40 m. per second?

I. $s = \frac{v^2}{2g} = \frac{96^2}{64} = 144$ ft. Or,

II: $t = \frac{v}{g} = \frac{96}{32} = 3$. Hence $s = 16 \cdot 3^2 = 144$ ft.

Also, $s = \frac{v^2}{2g} = \frac{40^2}{29} = 80$ m.

136. A freely falling body strikes the ground with a velocity of 1 meter. From what height has it fallen?

137. A falling body is precipitated vertically with a velocity of 14 feet per second, and reaches the ground with a velocity of 46 feet per second; required, the space passed over.

138. A body falls vertically from a certain height; three seconds after it started another body descends vertically from a height of 784 feet. From what height must the first body fall, if both bodies are to reach the ground at the same instant.

139. A body has been falling under gravity with an initial velocity of 5 m. per second. What is the space passed over in ten seconds?

140. A body falling freely from rest struck the ground with a velocity of 85 m. per second. For how long had it been moving, and what space did it describe in the last second of its fall?

Find the velocity.

142. A body has been falling freely 576 feet. What is its velocity at the end of its descent?

$v = \sqrt{2\,g\,s} = \sqrt{64 \cdot 576} = 192$ ft.

143. A body has been falling freely 55 m. What is its velocity at the end of its passage?

144. A body falls vertically from a height of 320 meters. Find the time spent, and the velocity acquired.

145. A body was 5½ seconds in falling vertically. Required the height of fall, and the velocity acquired.

146. With what velocity must a body be projected vertically downward to describe 296 feet in 4 seconds?

Find the time, s being known.

147. A body falls through a space of 1296 feet. Find the time required.

$(1296 = \frac{1}{2}\,g\,t^2 = 16\,t^2;\ \frac{1296}{16} = t^2;\ \frac{\sqrt{1296}}{\sqrt{16}} = t = 9$ sec.)

148. In what time would a body fall vertically from the height of a mile?

149. In what time will a body fall vertically from the height of a kilometer?

150. A body falls several seconds; during one of them it passes over 528 feet; which one is it?

PROJECTILES.

(In these examples bodies are supposed to move in *vacuo*; that is, without resistance.)

155. Prove that in vacuo a body projected vertically upward consumes the same amount of time in rising that it does in falling from the same height.

156. Show that in vacuo a body projected vertically upward returns to its starting point with the same velocity with which it was projected.

157. Show by a diagram the path of a projectile thrown horizontally, and moving during 4 seconds with a horizontal velocity of 100 feet per second.

158. Explain the path of a projectile thrown obliquely.

159. A ball is thrown vertically upward with a velocity of 96 feet, how high will it rise?

1st Solution. $s = \frac{v^2}{2g} = \frac{96^2}{64} = 144$ ft.

2d Solution. First find the time: $t = \frac{v}{g} = \frac{96}{32} = 3$ seconds.

Now, $s = 16 \cdot 3^2 = 144$ ft.

160. An æronaut (in a balloon at rest in the air) projects a body vertically downward with a velocity of 60 meters per second. After what time will the velocity of the body be 100

meters, and what space will it have then described? (g=10.)

(100 m. = 60 + g t; that is, 100 = 60 + 10 t) whence t = 4 seconds.

The space described is $s = (60 \cdot 4) + (5 \cdot 4^2)$, whence $s = 320$ m.)

161. A body is projected vertically upward with a velocity of 100 meters; how high will it rise?

162. A body is projected vertically upward with an initial velocity of 100 m. After a time x, another body, is projected vertically upward with the same velocity, and, after rising 8.5 seconds, meets the first. Find x, the time which elapsed between the two starts. (Take g = 10.)

Solution.—In redescending, projectiles have at every instant of their downward course the same velocity that they had when rising. Both projectiles having had the same initial velocities, their velocities at the instant of meeting are also the same. According to form. v = t g, the velocity of the rising body at the instant of meeting = 100 — (10 . 8.5). The velocity of the descending body at the instant of meeting also = t g, where t is the time employed in rising and descending to the point where both meet. This $t = 8.5 + x - \frac{100}{10}$; and $v = (8.5 + x - \frac{100}{10})$ 10; hence 100 — (10 . 8.5) = $(8.5 + x - \frac{100}{10})$ 10, whence x = 3 seconds.

163. How long will a body continue to rise if it is projected vertically upward with a velocity of 48 feet?

164. How long will a body continue to rise if projected vertically upward and attaining a height of 96 feet? How long will it be in the air?

165. How long will a body rise if thrown vertically upward with a velocity of 15 meters, and how long will it be in the air?

166. A body is projected vertically upward with a velocity

of 80 feet; give space passed over, 1st, during first second of its ascent; 2d, during last second of its descent.

167. A body is projected vertically upward with a velocity of 35 meters; give space passed over 1st, during first second of its ascent; 2d, during last second of its descent.

168. A projectile was impelled vertically upward, and rose to a height of 605 meters. Find the velocity with which it rose.

($v=\sqrt{2gs} = \sqrt{20.605} = 110$ m.)

169. With what velocity must a body be projected vertically upward to return to the starting place in 6 seconds?

170. A body is thrown vertically upward, and reaches the highest point of its flight in 5½ seconds. What must have been its velocity two seconds before this point was attained?

171. A body was projected vertically upward, and passed a certain point with a velocity of 80 feet per second. How much higher did it rise? (This question is equivalent to the following one:)

172. A body was projected with a velocity of 80 feet per second. How high did it rise?

173. In its vertical upward flight a body passed a certain point with a velocity of 18 meters per second. How much higher did it rise?

174. A body projected vertically downward with a velocity of 20 feet a second, passes through 100 feet in a certain second. Find over what space it passed in the preceding second.

175. A body projected vertically downward with a velocity of 4 meters a second, passes through 39 metres in a certain second. What space did it describe in the second preceding?

176. A ball is projected upward with a velocity of 160 feet per second, and two seconds afterward another ball is projected vertically upward with a velocity of 200 feet per sec-

end. Find their distance apart 5 seconds after the first ball was projected.

177. Two bodies are projected vertically upward, one with double the velocity of the other. How many times as high as the latter will the former rise?

178. A body is projected vertically upward with a velocity of 40 meters. How many seconds, and how high, will it rise?

179. A body projected horizontally from the top of a cliff, with a velocity of 40 feet per second, strikes the ground after 8 seconds. Find the distance of the point of fall from the point of projection.

180. If g on the moon is $\frac{1}{6}$ that on the earth, how high could a boy leap vertically on the moon, if on the earth he can leap two feet high?

FALL OF BODIES ON THE INCLINED PLANE.

Formulæ: $v = tg \cdot \frac{h}{l}$; $v = \frac{h}{l}\sqrt{2gs}$; $s = \frac{1}{2} g t^2 \cdot \frac{h}{l}$;

$s = \frac{v^2}{2g} \cdot \frac{h}{l}$; $t = \frac{h}{l}\frac{\sqrt{2s}}{\sqrt{g}}$

(In these examples friction is neglected.)

181. A ball rolls down an incline for 3 seconds, and passes over 7 feet the first second. Find the velocity acquired at the end.

Solution.—Since the space passed over under gr. during the first second $= \frac{1}{2}$ g, the velocity at the close of this second $=$ g, or twice the space described in the first second. Hence v $=$ g t $= (2 \cdot 7) \cdot 3 = 42$ ft.

182. A ball was ascending the same inclined plane in 3 seconds. What velocity had it when starting?

183. A body rolling down an inclined plane in 10 seconds acquired a velocity of 20 feet at the end of the first second. Find the final velocity.

184. What space did the same body describe in the first second, and what was the length of the incline?

185. The length of an incline is 800 feet, a body requires 10 seconds to descend it. What velocity does it acquire at the close of the first second?

186. A body descended an inclined plane of 64 feet vertical height and 256 feet in length. In what time, and with what velocity did it reach the base?

WEIGHT.

188. Define the *gravity* or weight of a body.

189. What is meant by mass?

190. Distinguish between the gravity and the mass of a body.

191. How do you find the gravity of bodies at a point below the surface of the earth?
surface of the earth?

192. If a stone weighs 10 pounds at the level of the ocean, how much would it weigh 1000 miles below the surface?

(The proposed place below the surface is 3000 miles from the earth's centre. Take this distance as a new radius. Then, by proportion, 4000 mi. : 3000 mi. :: 10 : x, whence x $= 7\frac{1}{2}$ lbs., answer.

Or, for every mile that the distance from the object to the centre of the earth is diminished, diminish the weight by $\frac{1}{4000}$. Now, 10 lbs. $-$ ($\frac{1000}{4000}$ of 10) $= 10 - 2\frac{1}{2} = 7\frac{1}{2}$ lbs.)

193. How far below the surface of the ocean must I place the stone, in the previous example, that it may weigh only one-fourth of a pound?

194. How far below the level of the ocean must a rock weighing a ton be placed in order that it may weigh only one-sixteenth of a ton?

195. How do you find the weight of bodies imagined to be placed above the surface of the earth?

196. A body weighs 1800 pounds at the earth's surface. What would be its weight 2000 miles above the surface?

(The proposed place being 2000 miles distant from the surface, we have a new imaginary radius (of the earth) of 6000 miles. Now, g varies inversely as the square of the distance; hence, by proportion, $4000^2 : 6000^2 :: x : 1800$ lbs., whence $x = 800$ lbs.)

197. What would be its weight 50 miles above the surface?

198. A meteorite was found, after striking the earth, to weigh 20 pounds. What was its weight 10 miles above the surface?

199. A body weighs 50 kilos. at the earth's surface. What would be its weight 2000 kilometers above the surface? (Take the radius of the earth = 6367 kilometers.)

200. How far above the surface of the earth must a pound weight be placed in order to have the gravity of one ounce (avoir.)?

201. State the law and formula of the intensity of gravity.

202. How does the intensity of gravity vary at different places on the earth's surface?

203. I suddenly jump off a platform with a 20 pound weight in my hand. What will be the pressure upon my arm while I am descending through the air? Explain your answer.

204. Define the centre of gravity.

205. What is meant by equilibrium?

206. Explain the different kinds of equilibrium, and illustrate each.

207. Define stability, and tell how it may be increased.

208 Must the centre of gravity of a body always be within the substance of the body?

209. Illustrate stable and unstable equilibrium by the case of a loaded sphere placed upon an horizontal plane.

210. Why is it easier to roll a round body than a square one?

211. Where is the centre of gravity of a triangle situated?

212. Two balls of uniform density, each 6 inches in radius, are placed side by side in contact; one weighs 12 lbs., the other 36 lbs. Find how far the centre of gravity of the two balls is from the centre of the heavier.

THE PENDULUM.

Formula: $t : T :: \sqrt{l} : \sqrt{L}$, or $t^2 : T^2 :: l : L$, in which t = the time which pendulum l requires to make one oscillation; and T = the time which pendulum L requires to make one oscillation.

215. What is meant by a physical pendulum? What is meant by a mathematical pendulum?

216. What is meant by the centre of suspension, and the centre of oscillation?

217. State the laws of the pendulum.

218. Illustrate the first two laws.

219. Illustrate the third law.

220. Express formula in the fourth law in ordinary language.

221. Two pendulums are respectively 4 feet and 9 feet long; the shorter uses two units of time (that is, a time of 2) for making one oscillation. What is the time used by the other for making one oscillation?

Solution.—The shorter the pendulum, the shorter the time it requires for one oscillation; the longer the pendulum, the longer the time required for one oscillation; and their lengths are to each other as the sqnares of their time. Hence $4 : 9 :: 2^2 : x^2$, whence $x = 3$ units of time.

222. One pendulum is 4 times as long as another. What is their relative time of oscillation?

223. Two pendulums are respectively 49 centimeters and 64 centimeters long. What is their relative time of oscillation?

224. A pendulum 16 inches long makes an oscillation in a unit of time. In what time will a pendulum 25 inches long make one oscillation at the same place?

225. If a pendulum 39 inches long oscillates seconds, what will be the time of its oscillations when it is lengthened one inch? (When lengthened, it is another pendulum, 40 inches long; whereas the former pendulum had a length of 39 inches.)

226. If a pendulum 1 meter long oscillates seconds, what will be the time of its oscillations when it is shortened 1 centimeter?

227. In New York City how long must a pendulum be to oscillate once in 3 seconds?

(Take the length of the second pendulum in New York City = 39.1 inches.)

228. Two pendulums make respectively 7 and 8 oscillations a minute. Find their relative lengths.

(Solution to problem 221 shows that the pendulum making 8 oscillations a minute is shorter than the one making 7 oscilla-

140. A body falling freely from rest struck the ground with a velocity of 85 m. per second. For how long had it been moving, and what space did it describe in the last second of its fall?

Find the velocity.

142. A body has been falling freely 576 feet. What is its velocity at the end of its descent?

$v = \sqrt{2\,g\,s} = \sqrt{64 \cdot 576} = 192$ ft.

143. A body has been falling freely 55 m. What is its velocity at the end of its passage?

144. A body falls vertically from a height of 320 meters. Find the time spent, and the velocity acquired.

145. A body was 5½ seconds in falling vertically. Required the height of fall, and the velocity acquired.

146. With what velocity must a body be projected vertically downward to describe 296 feet in 4 seconds?

Find the time, s being known.

147. A body falls through a space of 1296 feet. Find the time required.

$$(1296 = \tfrac{1}{2}\,g\,t^2 = 16\,t^2;\ \frac{1296}{16} = t^2;\ \frac{\sqrt{1296}}{\sqrt{16}} = t = 9 \text{ sec.})$$

148. In what time would a body fall vertically from the height of a mile?

149. In what time will a body fall vertically from the height of a kilometer?

150. A body falls several seconds; during one of them it passes over 528 feet; which one is it?

PROJECTILES.

(In these examples bodies are supposed to move in *vacuo*; that is, without resistance.)

155. Prove that in vacuo a body projected vertically upward consumes the same amount of time in rising that it does in falling from the same height.

156. Show that in vacuo a body projected vertically upward returns to its starting point with the same velocity with which it was projected.

157. Show by a diagram the path of a projectile thrown horizontally, and moving during 4 seconds with a horizontal velocity of 100 feet per second.

158. Explain the path of a projectile thrown obliquely.

159. A ball is thrown vertically upward with a velocity of 96 feet, how high will it rise?

1st Solution. $s = \frac{v^2}{2g} = \frac{96^2}{64} = 144$ ft.

2d Solution. First find the time: $t = \frac{v}{g} = \frac{96}{32} = 3$ seconds.

Now, $s = 16 \cdot 3^2 = 144$ ft.

160. An æronaut (in a balloon at rest in the air) projects a body vertically downward with a velocity of 60 meters per second. After what time will the velocity of the body be 100

meters, and what space will it have then described? (g=10.)

(100 m. = 60 + g t; that is, 100 = 60 + 10 t) whence t = 4 seconds.

The space described is $s = (60 \cdot 4) + (5 \cdot 4^2)$, whence $s = 320$ m.)

161. A body is projected vertically upward with a velocity of 100 meters; how high will it rise?

162. A body is projected vertically upward with an initial velocity of 100 m. After a time x, another body, is projected vertically upward with the same velocity, and, after rising 8.5 seconds, meets the first. Find x, the time which elapsed between the two starts. (Take g = 10.)

Solution.—In redescending, projectiles have at every instant of their downward course the same velocity that they had when rising. Both projectiles having had the same initial velocities, their velocities at the instant of meeting are also the same. According to form. v = t g, the velocity of the rising body at the instant of meeting = 100 — (10 . 8.5). The velocity of the descending body at the instant of meeting also = t g, where t is the time employed in rising and descending to the point where both meet. This $t = 8.5 + x - \frac{100}{10}$; and $v = (8.5 + x - \frac{100}{10})\ 10$; hence $100 - (10 \cdot 8.5) = (8.5 + x - \frac{100}{10})\ 10$, whence x = 3 seconds.

163. How long will a body continue to rise if it is projected vertically upward with a velocity of 48 feet?

164. How long will a body continue to rise if projected vertically upward and attaining a height of 96 feet? How long will it be in the air?

165. How long will a body rise if thrown vertically upward with a velocity of 15 meters, and how long will it be in the air?

166. A body is projected vertically upward with a velocity

of 80 feet; give space passed over, 1st, during first second of its ascent; 2d, during last second of its descent.

167. A body is projected vertically upward with a velocity of 35 meters; give space passed over 1st, during first second of its ascent; 2d, during last second of its descent.

168. A projectile was impelled vertically upward, and rose to a height of 605 meters. Find the velocity with which it rose.

($v=\sqrt{2gs} = \sqrt{20.605} = 110$ m.)

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FALL OF BODIES ON THE INCLINED PLANE.

Formulæ: $v = t g \cdot \frac{h}{l}$; $v = \frac{h}{l}\sqrt{2gs}$; $s = \frac{1}{2} g t^2 \cdot \frac{h}{l}$; $s = \frac{v^2}{2g} \cdot \frac{h}{l}$; $t = \frac{h}{l}\frac{\sqrt{2s}}{\sqrt{g}}$

(In these examples friction is neglected.)

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WEIGHT.

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surface of the earth?

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(The proposed place below the surface is 3000 miles from the earth's centre. Take this distance as a new radius. Then, by proportion, 4000 mi. : 3000 mi. :: 10 : x, whence x = $7\frac{1}{2}$ lbs., answer.

Or, for every mile that the distance from the object to the centre of the earth is diminished, diminish the weight by $\frac{1}{4000}$. Now, 10 lbs. — ($\frac{1000}{4000}$ of 10) = 10 — $2\frac{1}{2}$ = $7\frac{1}{2}$ lbs.)

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212. Two balls of uniform density, each 6 inches in radius, are placed side by side in contact; one weighs 12 lbs., the other 36 lbs. Find how far the centre of gravity of the two balls is from the centre of the heavier.

THE PENDULUM.

Formula: $t : T :: \sqrt{l} : \sqrt{L}$, or $t^2 : T^2 :: l : L$, in which t = the time which pendulum l requires to make one oscillation; and T = the time which pendulum L requires to make one oscillation.

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220. Express formula in the fourth law in ordinary language.

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Solution.—The shorter the pendulum, the shorter the time it requires for one oscillation; the longer the pendulum, the longer the time required for one oscillation; and their lengths are to each other as the sqnares of their time. Hence $4 : 9 :: 2^2 : x^2$, whence $x = 3$ units of time.

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223. Two pendulums are respectively 49 centimeters and 64 centimeters long. What is their relative time of oscillation?

224. A pendulum 16 inches long makes an oscillation in a unit of time. In what time will a pendulum 25 inches long make one oscillation at the same place?

225. If a pendulum 39 inches long oscillates seconds, what will be the time of its oscillations when it is lengthened one inch? (When lengthened, it is another pendulum, 40 inches long; whereas the former pendulum had a length of 39 inches.)

226. If a pendulum 1 meter long oscillates seconds, what will be the time of its oscillations when it is shortened 1 centimeter?

227. In New York City how long must a pendulum be to oscillate once in 3 seconds?

(Take the length of the second pendulum in New York City = 39.1 inches.)

228. Two pendulums make respectively 7 and 8 oscillations a minute. Find their relative lengths.

(Solution to problem 221 shows that the pendulum making 8 oscillations a minute is shorter than the one making 7 oscilla-

tions in the same time. Therefore, its time for one oscillation must also be shorter than the time used by the other. Now, the time of oscillation of two pendulums of unequal lengths is inversely as their respective numbers of oscillations. Hence according to form, $t^2 : T^2 :: l : L$, and assuming the length to be 1, we have $7^2 : 8^2 :: 1 : x$, whence $x = \frac{6}{4}\frac{4}{9}$. Hence the answer: As 1 is to $1\frac{5}{9}$.)

229. A pendulum 1 meter long makes 40 oscillations in a given time. How long must a pendulum be to make 60 oscillations in the same time and at the same place?

230. In New York City how long must a pendulum be to oscillate in $\frac{1}{2}$ second?

231. A pendulum 4.5 feet long makes 45 oscillations in a given time. How long must a pendulum be to make 60 oscillations in the same time and at the same place?

232. A pendulum 1.5 meters long makes 400 oscillations in a given time. How many oscillations will it make during the same time, if the rod has expanded $\frac{1}{4}\frac{1}{0}\frac{1}{0}$ of its former length?

233. A small, heavy ball is suspended by a thread from a point, and makes small oscillations. The thread is shortened by two feet, and now the number of oscillations per minute is increased in the ratio of 4 to 3. Find the original length of the thread. (S. K.)

234. A pendulum clock loses two seconds each day. How much must it be shortened to keep correct time?

235 A pendulum, the length of which is 1.9$\dot{5}$ m., makes 61682 oscillations in a day. Required the length of the seconds pendulum.

(*Examples on Formula* $t = \pi \frac{\sqrt{l}}{\sqrt{g}}$, in which t = time for one oscillation; $\pi = 3, 1416$; l = length of the pendulum, and g = the acceleration of gravity at the place.)

236. The length of the seconds pendulum at Spitzbergen being 39.216 inches, what is the intensity of gravity at the same place?

237. The length of a seconds pendulum at the equator being 39.022 inches, what is the intensity of gravity at the same place?

238. The intensity of gravity at a given place is 32.2. Required the length of the seconds pendulum at the same place.

FORCE

(*Formula for General Equation of Force:* $F = m\,c$, in which F stands for any force acting for one second upon a mass m; and c = the velocity generated (in feet per second). Since the mass of a body = its weight W divided by g, the gravity at the place, we also have $F = \frac{W}{g}\,c$.)

250. What are the ways in which force may be measured?

251. Define work.

252. What is a footpound? A kilogrammeter?

253. Distinguish between the *mass* and the *weight* of a body.

254. What is the magnitude of a force which in one second can generate in a mass of 40 a velocity of 6 feet per sec.?

Solution.—$F = m\,c = 40 \cdot 6 = 240$, answer. That is, the force exerts the same vertical pressure as a mass of 240.

255. What is the magnitude of a force which in one second can generate in a body weighing 40 lbs. a velocity of 6 feet per second? *Solution.*—$F = (\frac{W}{g})c = (\frac{40}{32})\,6 = 7\frac{1}{2}$ lbs.

256. Required the force producing motion, if a weight of 25 ounces be caused to move through 320 feet in 10 seconds.

(According to formula $s = (\frac{1}{2}g)\,t^2$, we have $320 = (\frac{1}{2}c)\,10^2$, whence c = 6.4 feet, the acceleration per second. Now, $F = \frac{W\,c}{g} = \frac{25(6.4)}{32} = 5$ oz., answer.)

257. Required the magnitude of a force which in one

second can give a body weighing 112 lbs. a velocity of 10 feet per second.

258. A force of 8 ounces causes a certain mass to move from rest with a velocity of 4 feet per second; required the weight of the mass.

259. A body is started from a state of rest by an accelerating force of 12 meters per second, and passes over a space of 3750 meters. Find the time.

(Let g = the accelerating force; then, according to formula $s = \frac{1}{2} g t^2$, we have $3750 = \frac{12}{2} t^2$, whence $t = 25$ sec.)

260. Given a force of 7.5 lbs., acting on a mass whose weight = 40 lbs. For how long a time must the force act upon the mass to produce a velocity of 48 feet per second?

261. A locomotive moves at the rate of 30 miles an hour when the steam is shut off; the friction = $\frac{1}{320}$ the weight of the locomotive. Find the time that will elapse before it stops.

262. Two bodies, whose masses are m and $3\ m$, are moved by forces 3 p and p respectively. Compare the spaces they describe in t seconds.

Solution. — $\frac{F\,g}{W} = c$, or $\frac{W}{g} = \frac{F}{c}$; hence mass $m = \frac{F}{c} = \frac{3\,p}{c}$, and mass $3\ m = \frac{F}{c} = \frac{p}{c}$. That is, the velocities of both masses are to each other as $\frac{3\,p}{c}$ is to $\frac{p}{c}$, or as 3 : 1. Hence the spaces described are to each other as $3^2 : 1^2$; that is, as 9 : 1.

263. A body starting from a state of rest is acted upon by an accelerating force, which impressess upon it an acceleration of 5 m. per second. What will be the space it describes in 10 seconds?

264. If a force of 10 pounds in a certain time gives a body

a velocity of 9 feet per second, what velocity will a force of 25 pounds impart to the same body in the same time? R.

265. If a force of 36 pounds imparts a velocity of 5 feet to a mass of 100 pounds, what mass will in the same time, place and circumstances receive a velocity of 6 feet from a mass of 45 pounds?

266. If a force of 6 pounds gives to a certain mass a velocity of 20 feet per second in 4 seconds, what vel. will a force of 4 pounds give to twice the mass in 6 seconds? (M.)

267. A body is subjected to the action of an accelerating force of 10 meters per second. What will be its velocity at the end of fifteen minutes? (60 • 15 • 10 = 9000 m.)

268. A body under the influence of an accelerating force (of constant ratio) passes over a space of 360 m. in 6 seconds. Required the intensity of the accelerating force.

($360 = \frac{g}{2} 6^2$, whence g = 20 m. per second.)

269. What was the space passed over by the body in the previous example during the last second?

(If in 6 seconds it describes 360 m, it will in five seconds describe $\frac{20}{2} \cdot 5^2 = 250$ m., and in the sixth second it will pass over 360 — 250 = 110 meters.)

270. A canon ball was projected vertically upward with a velocity of 500 meters per second. After how many seconds was its velocity reduced to 300 m. (under the retarding influence of gravity), and what space had it passed over? (g = 10 m.)

271. A body impressed with an initial velocity, whose amount or intensity is unknown, is acted upon by a retarding force of 20 m. per second in the opposite direction, in consequence of which it comes to rest at the end of 30 seconds. Find the intensity of the initial velocity.

ENERGY.

(Formula of Kinetic Energy $= \frac{1}{2}mv^2$, in which m = the mass (or $\frac{W}{g}$) of the moving body, v = its velocity per sec.)

280. State what is meant by energy, by kinetic energy, and by potential energy.

281. Explain the great natural principle from which fly-wheels derive their efficiency. (S. K.)

282. State briefly how a fly-wheel equalizes the motion of machinery. (S. K.)

283. How is the energy of a fly-wheel affected by

(1) Giving it twice the weight?

(2) By giving it twice the diameter (the weight and number of revolutions remaining the same)?

(3) By giving it twice the number of revolutions in a given time?

Answers—(Friction neglected)—(1) The energy becomes twice as great. (2) The energy becomes four times as great. (3) The energy becomes four times as great.

Explain each answer.

284. Required the kinetic energy, or "vis viva," of a body whose mass = 10, and whose v = 1000 feet per second.

Solution.—$(\frac{1}{2}$ m) $v^2 = 5 \cdot 1000^2 = 5000000 = \frac{5000000}{32}$ 156250 footpounds.

285. Required the "vis viva" of a body weighing 96 pounds, moving with a velocity of 1000 feet per second.

286. Find the kinetic energy of a 24 pound ball, moving at the rate of 2000 feet per second.

287. Find the kinetic energy of 5 cub. meters of water that flow every second through a channel with a velocity of 3 meters.

288. Find the kinetic energy or striking force of a 96 pound cannon ball, flying with a velocity of 1500 feet.

289. What would be the kinetic energy of a pebble weighing one-half ounce, and striking the earth after falling two seconds?

290. If a gun with a certain charge of powder cause a hundred-pound shot to ascend vertically for three seconds, through what height will a fifty pound shot ascend with three times as great a charge? (M.)

Answer.—5184 feet high. (The height to which a body can be projected varies *directly* as the square of the projecting force, and *inversely* as the square of the mass projected.)

291. If a shot weighing one ounce, and projected with n ounces of powder, rises 200 feet high, how high will a shot rise that weighs three ounces, and is projected with $2n$ ounces of powder?

292. An arrow shot from a bow starts off with a velocity of 120 feet per second. With what velocity will an arrow twice as heavy leave the bow, if sent off with three times the force? (M.)

293. If a ball fired from a gun rise to a height of 150 feet, to what height will a ball half again as heavy rise if fired with twice the charge of powder? (M)

294. Two balls weighing 8 and 6 ounces respectively are simultaneously projected upward. The former rises to a height of 324 feet, and the latter to one of 256 feet; compare the forces of projection. (M.)

WORK.

300. Define *Work.*

301. What is a unit of work, and what a horse-power?

302. How do you measure work, or mechanical energy?

303. Can you destroy work by any combination of machines?

304. Point out the absurdity of perpetual motion.

305. How much work is done per hour, if 100 pounds be raised 3 feet high per minute?

Solution.— To raise 100 pounds one foot high = 100 footpounds of work per minute; to raise 100 pounds three feet high = 300 footpounds of work per minute, and in one hour = 60 . 300 = 18000 footpounds of work.

306. How many units of mechanical work will be expended in raising 10 cub. feet of water 100 feet high? (A cub. ft. of water weighs 62.5 lbs.)

307. Five hundred cubic feet of water per minute are raised by pumping to a height of 200 feet. Find the work done per minute in footpounds and the rate of doing work in h rses-power. (S. K.)

308. How many gallons of water would a steam engine of 10-horse-power raise from a depth of 1000 feet in an hour?

(A gallon of water weighs 10 pounds.) (S. K.)

309. What power of steam engine will be required to raise 10 tons of coal per hour from a mine whose depth is 600 feet? (S. K.)

310. A weight of 3 tons is raised through 50 feet. How many units of work must be done by the agent?

311. If the weight is raised in one-fourth of a minute, what must be the horse-power of the agent?

312. A man works on a machine in such a manner as to do 1,000,000 units of useful work in a day of 8 hours. The machine is so arranged that he can lift a mass of 5 cwt. How long will it take him, working at his daily average rate, to lift that weight through a height of 100 feet? (S. K.)

313. A bricklayer's laborer with his hod weighs 170 lbs.; he puts into the hod 20 bricks weighing 7 pounds each; he then walks up a ladder to a vertical height of 30 feet. How many units of work does he do? And if he can do 1,500,000 units of work per day, how many bricks will he take up the ladder in a day? (S. K.)

IMPACT OF BODIES.

($V = \frac{m\,v + m'\,v'}{m + m'}$, in which m and m' represent the masses of inelastic moving bodies; v and v' their respective velocities per second; V their common velocity after impact.)

315. Explain the impact of inelastic bodies, and give formula.

316. Explain the impact of elastic bodies.

317. Explain why in the impact of inelastic bodies there is great loss of energy, while in that of elastic bodies the loss of energy is very small.

318. A and B are two inelastic balls whose weights are 6 pounds and 10 pounds respectively. A, with a velocity of 9 feet per second, meets B moving with a velocity of 4 feet per second. With what velocity and in what direction will they move directly after impact?

Solution.—A's momentum $= m\,v = 6 \cdot 9 = 54$

B's " $= m'\,v' = 10 \cdot 4 = 40$

$\frac{m\,v - m'\,v'}{m + m'} = \frac{(54 - 40)}{(6 + 10)} = \frac{7}{8}$ ft. common velocity in A's direction after impact.

319. There are two bodies whose masses are 15 pounds and 20 pounds respectively. The former, moving at the rate of 12 feet per second, overtakes and impinges directly on the latter moving at the rate of 6 feet a second. Find their common velocity at the end of the impact, and their joint energies just before and after impact. (S. K.)

320. An inelastic body weighing 25 kilos. moves with a velocity of 3.75 meters. It is struck by another inelastic body weighing 40 kilos., whose velocity = 7 m., and whose motion is opposite to that of the first. With what velocity and in what direction will both bodies move after impact? (B.)

321. Find the momenta and kinetic energies of the two bodies in the previous example, both before and after impact.

322. With what velocity and in what direction will both bodies move after contact if their motions originally have the same direction?

323. Find the kinetic energies of the two bodies after impact, if the conditions are the same as in example 322.

324. Two inelastic bodies, weighing together 800 pounds, move against each other. One has a velocity of 40 feet, the other a velocity of 60 feet. After impact both move on with a velocity of 25 feet. Find the weight of each body. (B.)

325. Two inelastic bodies, respectively weighing 18 and 24 pounds, move in the same direction. After impact both have a velocity of 8 feet; the original velocity of the first body was to that of the second as 2 is to 3. Find the velocity each had before impact. (B.)

326. It will be observed that the pavior employs a wooden ram wherewith to imbed stones. Those who break stones at the roadside use a small, elongated hammer with a long, supple handle or shaft. Will you explain the natural principles that are involved in these and similar devices? (S. K.)

CENTRIFUGAL FORCE.

(*Formula* $\frac{m\ v^2}{r}$, in which m = mass of the revolving body; v = its velocity; r = the radius of the circle,)

330. What is meant by centrifugal force? What, by centripetal force?

331. Find the centrifugal force of a two-ounce leaden ball at the end of a string 3 feet in length, and rotating around the other end of the string with a velocity of 50 feet.

Solution. — Since mass $= \frac{W}{g}$, the mass of the ball $= \frac{2}{32}$; hence $\frac{m\ v^2}{r} = \frac{(\frac{2}{32})\ 50^2}{3} = 52\frac{1}{2}$, ozs. answer.

332. A body weighs 40 kilos.; it moves in a circle of 5.6 m. radius, with a velocity of 22 m. Find its centrifugal force.

333. A pail filled with water is whirled in a horizontal circle of 38 inches radius, so as to perform two revolutions a second. Its cubic contents = ½ cubic foot. State with what force the water is forced against the bottom of the pail.

334. An apple weighing two ounces is tied to one end of a string 3 feet in length, and whirled round three times a second. Required its centrifugal force.

335. At the equator the centrifugal force is $\frac{1}{289}$ of the intensity of gravity. What must be the velocity of rotation of the earth in order that the centrifugal force may equal the force of gravity? (Solution on next page.)

(Let v = the actual velocity, and v' = the unknown velocity, then, as centrifugal force varies directly as the square of the velocity—

$$v^2 : v'^2 :: g : 289\ g,$$

whence $v'^2\ g = v^2 \cdot 289\ g,$

or $v'^2 = 289\ v^2,$

and $v' = v\sqrt{289} = 17\ v.$

That is, the rotary velocity of the earth must be 17 times as great.)

FRICTION.

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336. What is friction? What is the difference between rolling and sliding friction?

337. What kind of friction between the ground and the feet of a person walking?

338. Explain fully the nature of the resistance termed "friction," and state the laws by which it is governed, so far as they apply to machinery; and likewise mention some of the means that are employed to diminish its effect so far as may be practicable. (S. K.)

339. What is the object of having bronze or other peculiar metal as the bearings or bushes of machinery for iron axles to run or work upon? (S. K.)

340. A body weighing 100 pounds is moved on a horizontal plane by a force of 12 pounds. Find the coefficient of friction. Answer, 0.12.

341. A body weighing 20 kilos., and moving on a horizontal plane, requires a force of 500 grams to keep it in motion. Find the coefficient of friction.

342. A sleigh containing two persons, weighs 450 pounds, and moves on an horizontal track. The coeff. of friction being 0.08, find the force required to keep the sleigh in motion.

Solution.—$450 \cdot (0.08) = 36$ pounds.

343. A cast iron plate having a weight of 2000 pounds is nicely planed and smoothed upon its under surface, in order that it may slide easily on carefully prepared brass or gun-metal bearings, which are properly lubricated with good oil. What amount of friction, expressed in pounds, will have to be overcome in giving it a sliding motion? (Coefficient of friction, 0.06.)

344. A body is moving with a velocity of 100 feet. Assuming that the resistance of the air amounts to 15 pounds, what will be the resistance if the same body moves with a velocity of 120 feet?

(The two resistances are to each other directly as the squares of the velocities.)

345. The front end of a railway car has a surface of 90 square feet. When the car moves with a velocity of 25 feet, the resistance of the air in front is 10 pounds for every square foot. What will the resistance be when the car moves with a velocity of 40 feet?

346. The resistance of the air tends to convert the motion of a freely falling body into uniform motion. Explain this.

MACHINES.

350. What is a machine?

351. Define the terms *power* and *weight.*

352. Tell what is meant by "internal resistance," and illustrate by the steam engine.

353. State the general law of machines in equilibrium, and give equation.

354. Mention the simple mechanical powers.

355. State the general law of mechanical powers, and illustrate by means of the movable pulley.

356. How do you find the mechanical advantage of a machine, or the power gained by it?

357. Show that no machine ever creates power or energy.

358. What is meant by the amount of "useful work" of a machine?

359. What is meant by the entire "effect" of a machine?

LEVERS.

(W : P :: L : l, where W = weight; P = force required to balance W; L = distance between P and the fulcrum; l = distance between W and fulcrum.)

360. What is a lever? How are the different orders of levers distinguished from one another?

361. State the rule for finding how one weight will balance another on a straight lever.

362. How do you find the advantage gained by a lever?

363. A small weight at one end of a lever raises a big weight at the other end. Show that there is, nevertheless, no energy created by a lever.

364. Classify the following objects according to the order of levers to which they belong:

Knife,	Pincers,	Spade,	Oar of row-boat,
Shears,	Tweezers,	Ax,	Hammer,
Auger,	Lemon-squeezer,	Bow,	Human arm,
Wheel-barrow,	Sugar-tongs,	Crowbar,	Chisel,
Key,	Fork,	Chopping-knife,	Nut-cracker.

LEVERS.

(Remember: When there is a slight excess of force on either side, the lever will commence to turn. In this case the work done is the same on either side *minus* the surplus of work produced by that slight excess, which, in these examples, is neglected. Illustrate every example by a drawing.)

370. The F (fulcrum) of a lever 10 feet long is 2 feet from one end; at this end hangs a W (weight) of 80 pounds. What force (P) at the other end will balance it?

(W : P :: L : l,

80 : x :: 8 : 2, whence x = 20 pounds.)

371. The F of a lever is 1 foot from one end and 4 feet from the other. What is the advantage gained? What is the effect if the P applied = 1 pound?

372. Find the power required to raise the weight in example 370, if the friction at the fulcrum amounts to one-fourth of the advantage gained.

373. Find the weight of a rock lifted by means of a crowbar 8 feet long; F 1 foot from one end, P = 30 pounds.

374. Two weights of 6 and 8 pounds respectively are to be suspended from the ends of a lever 7 feet long. Where must the F be placed so that the weights may balance?

375 Length of lever, 0.7 m. At its ends are two forces, respectively of 40 and 30 kilograms. Find position of F.

376. A heavy rod 12 inches long balances at a point 3 inches from the end. Will it continue to balance about that point if equal weights be attached to both ends?

377. If 16 pounds balance 20 ounces at the ends of a lever 8 feet long, where is the F (neglecting the weight of the lever)? (S. K.)

378. A force of 35 pounds at one end of a lever is in equilibrium with a weight of 50 cwt. at the other end. If I wish to raise the weight one inch, through what space will the power pass in the same time?

379. The F of a lever 3 meters long is 60 centimeters from one end; at this end is a force of 40 kilograms. What force, if applied at the other end, will balance the lever?

380. A crowbar 2 meters long is supported 25 centimeters from one end. How great a weight may be lifted by means of a power of 15 kilograms?

381. Two weights, 3 and 5 kilograms respectively, are to be suspended from the ends of a lever 3.60 meters long. Where must the F be placed so that the weights balance?

382. A and B carry a heavy object on a rod between them, each holding one end of the rod. The rod is 11 feet long, and A's strength is 1¾ that of B. Where should the object be suspended?

(Let x = distance between A and W (the object); then (11 — x) = distance between B and W. Now, 1 : 1¾ :: x : (11 — x), whence x = 4 feet from A.)

383. Two horses, one of 800 pounds, the other of 900

pounds pulling capacity, are to draw a carriage. How far from the centre of the axle should each whipple-tree be fastened, the axle being 3 feet long?

384. A and B wish to carry a load weighing 880 pounds on a rod between them. A's strength is 4 times that of B; the rod is 8 feet long. Where must the weight be attached, and how much will each carry?

385. A and B carry a weight of 240 kilograms on a rod between them. A's strength is 4 times that of B; the rod is 3 m. long. Where should the weight be suspended, and how much of it will each carry?

386. A lever five feet long, with F two feet from one end, is balanced by two forces, one acting at each end. The sum of both forces is 1200 pounds; find the amount of each.

387. A rod is acted upon by three forces, acting vertically downward, of 2, 4 and 12 pounds respectively. Show how they may be adjusted to be in equilibrium.

388. To a weightless, rigid rod, 30 inches long, weights of 4, 6, 8 and 12 pounds are fixed at equal distances from one another. Where must the rod be suspended to rest horizontally? (M.)

389. A rod of uniform density 6 feet long has a weight of 2 pounds tied to one end; the rod will balance on a fulcrum placed 6 inches from that end. What is the weight of the rod? (S. K.) (Conceive the weight of the rod to act as a weight suspended from the centre of the rod.)

390. A horizontal straight bar 6 feet long and weighing 16 pounds is supported at each end; and a weight of 48 pounds is suspended 2 feet from one end. Find the pressure upon each of the supports.

391. In example No. 374 where must the F be placed if the weight of the lever, 2 pounds, be considered?

392. Where must the F in example 381 be placed if the weight of the lever, 1 kilogram, be taken into account?

393. A lever is in equilibrium under the action of the forces P and Q, and is also in equilibrium when P is trebled and Q increased by 6 pounds. Find the magnitude of Q. (To.)

394. A plank weighing 10 pounds rests on a single prop at its middle point; if the prop be replaced by two others on each side of it, 3 feet and 5 feet from the middle point, find the pressure on each. (M.)

395. A lever 7 feet long is supported in a horizontal position by props placed at its extremities. Find where a weight of 28 pounds must be placed so that the pressure on one of the props may be 8 pounds. (To.)

396. A plank weighing 5 kilograms rests on a single prop at its middle point. If this prop be replaced by two other props, one on each side of it, and respectively 0.4 and 0.6 m. from the middle point, what will be the pressure on each prop?

397. Two weights of 12 and 8 pounds respectively, balance at the ends of a horizontal lever 10 feet long. Find how far the fulcrum ought to be moved for the weights to balance when each is increased by 2 pounds. (To.)

398. A B C is a straight lever; the length of A B is 7 inches, that of B C is 3 inches; weights of 6 and 10 pounds hang at A and B, and an upward pressure of 6 pounds acts at C. Find the position of a fulcrum about which the lever so acted upon would balance. (To.)

399. The short arm of a lever is two feet long, and at its end hangs a weight of 500 pounds. What must be the entire length of the lever, if a P of 200 pounds at the other end is to raise the weight?

400. What is the advantage gained by a compound lever

whose short arms = 1, 2 and 3 feet respectively, and whose long arms are 6, 7 and 8 feet respectively. Loss by friction = $\frac{1}{7}$ of the advantage gained.

401. Three levers, each having a short arm 1 foot long, and a long arm 4 feet long, are made into a compound lever. What force at the end of the last short arm can be balanced by a force of 1 pound acting at the free end of the long arm?

402. Find the advantage gained by a compound lever whose short arms are 30, 40 and 50 centimeters respectively, and whose long arms = 3, 4 and 5 meters respectively. Loss by friction = $\frac{1}{10}$ of the advantage gained.

403. A substance is placed in one pan of a balance, and requires 3262 grams to hold it in equilibrium. It is then placed in the other pan, and now requires 3140 grams to balance it. What is the actual weight of the body (rejecting small remainders)?

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410. What force must be applied at the free end of a lever 4 feet long to balance a weight of 100 pounds hung up 1 foot from the other (fixed) end?

(P : W :: l : L; hence x : 100 :: 1 : 4, whence x = 25 pds.)

411. What force will balance a weight of 200 kilograms suspended 0.5 m. from the end of a fixed lever 4 m. long?

412. A lever is 4 feet long; 6 inches from one end (F)

hangs a weight which is balanced by a force of 30 pounds at the other end. Required the amount of the weight.

413. A lever is 2.40 m. long, and 60 centimeters from its fixed end hangs a weight balanced at the other end by a force of one-half kilogram. Find the weight.

414. A lever 8 feet long, with its fulcrum at one end is maintained in a horizontal position by two forces of 10 pounds and 160 pounds respectively. How far from the fulcrum may the latter be? And what is the pressure upon the fulcrum? (Place the smaller weight at the free end.)

415. A lever 6 feet long is held horizontal by two forces whose sum = 400 pounds; one of them is applied at one end of the lever, the other at a distance of 3 inches from the other end (F). Find the amount of each force.

416. The sum of two forces is 500 kilograms; one of them operates at the end of a lever 9.55 m. long, the other 45 centimeters from the other end. Find the amount of each force.

417. The weight of a uniform rod 8 feet long is 1 pound; a weight of 10 pounds is suspended two feet from the fixed end. Find what force at the other end will balance the lever.

418. A rod 4 m. long is inserted 0.5 m. deep in a wall; a weight of 80 kilograms hangs from the free end of the rod. Find the pressure on the edge of the opening in the wall.

419. A chopping knife 15 inches long is acted upon by a power of 10 pounds. The resistance is equivalent to a weight of 37.5 pounds; how far from the fulcrum should it be placed?

420. A man is rowing a boat; each oar is 10 feet long, and fastened to the boat 7½ feet from the immersed end of the oar; the power he exerts at each oar = 25 pounds. What resistance does the boat meet with?

421. A nut is placed in a pair of nut crackers at a distance

of one inch from the joint; a pressure of 6 pounds applied to each lever 5 inches from the joint is just sufficient to crack it. What resistance does the nut offer?

422. A horizontal rod has a length of 4 feet; one of its ends is fastened to a wall, the other bears a large, wooden watch sign weighing 25 pounds. What must be the least bearing capacity of a wire that upholds the rod 1½ feet from the sign? (The weight of the rod neglected.)

423. The safety-valve of a steam boiler is required to open when the steam pressure reaches 50 pounds per square inch. What weight will be required upon the extremity of the safety-valve lever, the valve being 3 inches in diameter, the entire length of the lever 24 inches, and the distance between the fulcrum and the center of the valve being 3 inches? (S. K.)

WHEEL AND AXLE.

(In these examples the increase in the diameter when the rope is winding round the axle is neglected.)

430. Describe the wheel and axle, and tell how it differs from a lever of the first class.

431. What is the rule for finding how one weight will balance another on a wheel and axle?

432. How do you find the advantage gained by a wheel and axle?

433. Mention two common forms of the wheel and axle.

434. What is the mechanical advantage of a wheel and axle in which the radius of the axle is $1\frac{1}{2}$ inches, and that of the wheel 15 inches.

(Substituting r, the radius of the axle, for l in the proportion for the lever, and R, radius of wheel, for L in the same, we have, $\begin{matrix} P : W :: r : R, \\ 1 : x :: 1\frac{1}{2} : 15 \end{matrix}$ whence $x = 10$. The mechanical advantage $= \frac{10}{1} = 10$.)

435. If a weight of 160 pounds be supported on a wheel whose diameter is 20 inches, the diameter of the axle being 5 inches; what force will sustain the weight?

436. What power is required to lift a ton of ore by means of a wheel and axle of $8\frac{1}{3}$ feet and 10 inches diameter respectively?

437. An anchor is hoisted by a capstan worked by 4 men, each pushing at the end of a handspike; the diameter of the circle described by the four handspikes is 6 feet 8 inches; the diameter of the barrel of the capstan is 8 inches; the anchor weighs 2400 pounds. What is the pressure exerted by each man?

438. A capstan 14 inches in diameter is worked by 8 men, and by means of 4 levers each 7 feet long. At the end of each lever a man is pushing with a force of 30 pounds; 2 feet from the end another man pushes with a force of 42 pounds. What is the effect produced?

439. A capstan 14 inches in diameter is worked by means of a horse harnessed to the end of a lever 7 feet long. How long will a horse be in pulling a house over a space of 5 miles if walking at the rate of 2½ miles an hour?

440. If the radii of a wheel and axle be as 10 is to 4, and weights of 3 and 8 ounces hang from them; which will descend? (M.)

441. A man whose weight is 140 pounds is just able to support a weight that hangs over an axle of 6 inches radius by hanging to the rope that passes over the corresponding wheel, the diameter of which is 4 feet. Find the weight supported. (M.)

442. If the difference between the diameter of a wheel and the diameter of the axle be six times the radius of the axle, find the greatest weight that can be sustained by a force of 60 pounds. (M.)

443. If the radius of the wheel be n times as great as that of the axle, and t be the maximum tension of the string on the wheel, find the greatest weight that can be raised. (M.)

444. If a weight of 30 ounces be supported on a wheel and axle by a force of 2 ounces, and the radius of the wheel is 6 feet 3 inches, find the radius of the axle.

445. Find the mechanical advantage of a wheel and axle in which the radius of the axle is 4 centimeters and the radius of the wheel 0.52 meters.

446. If a weight of 100 kilograms be supported on a wheel whose diameter is 0.5 m., the diameter of the axle being 0.05 m., what force will sustain the weight?

447. Find the power required to lift 800 kilograms of ore by means of a wheel and axle of 2 and 0.2 meters diameter respectively.

448. The drum of a capstan is 18 inches in diameter, and the handspikes are 10 feet long. Four men are employed to raise weights from a depth of 50 feet by this machine. Assuming that when a man exerts a continuous force in pushing or pulling 27 pounds, he can do the greatest amount of daily work — viz.: 1500000 units, determine the load that should be raised at each lift, and the total load raised daily. (Passive resistances and weight of rope and box to be neglected.) (S. K.)

449. Wherein does the differential wheel and axle differ from the common wheel and axle?

450. How do you find the advantage gained by means of the differential wheel and axle?

451. Explain why in the differential wheel and axle the work done by W, in unit of time, is $W\left(\frac{r-r'}{2}\right)$?

(In this formula W = the weight or load; r = the radius of larger axle, r′ = that of smaller axle.)

452. Two men, at opposite ends of a differential axle, each pushing with a force of 20 pounds, are turning a crank of 1½ feet in length; the diameters of the axles are 10 inches and 8 inches respectively. Find the weight that may be raised, two-tenths of the effect being lost by friction.

453. What load may be lifted by means of a power of 50 kilograms acting upon a differential wheel and axle, if the crank is 0.38 m. long, and if the radii of the greater and smaller axles are 0.135 m. and 0.127 m. respectively?

(*Solution:* 50 : x :: ½ (0.135—0.127) : 0.38
= 50 : x :: 0.004 : 0.38, whence x = 4750 kil.)

454. In the above example how many revolutions must the crank perform while the load is lifted 1 meter?

455. With the same crank, as in example 453, how large would a single axle have to be in order to yield the same advantage as the machine in example 453?

TOOTHED WHEELS.

$$\text{Adv. gained} : \frac{\text{Product of teeth of wheels} \cdot \text{circle by power.}}{\text{Product of leaves of pinions} \cdot \text{circumf. of axle.}}$$

460. How do you find the advantage gained by a system of toothed wheels?

461. In a train of three toothed wheels and three pinions, the first wheel has 50 teeth, and its axle (from which the weight is suspended) has a circumference of 10 inches. The wheel is moved by a pinion of 10 leaves on a wheel of 40 teeth; this wheel is moved by a pinion of 10 leaves on a wheel of 50 teeth; and this wheel is turned by a pinion of 10 leaves on a wheel of 80 inches circumference, at which the power acts. Find the value of, that is, the advantage gained by, the train.

462. A large block of stone is lifted by means of a derrick and suspended from a movable pulley. The rope of the pulley, after passing over a fixed pulley at the top of the derrick, descends and winds around a drum of 6 inches radius, having at each end a toothed wheel of 100 teeth driven by a pinion

of 10 leaves. Each pinion is moved by means of a crank 1½ feet long, each crank being turned by a laborer with a force of 25 pounds. Find the weight of the stone, three-fifths of the power applied being lost by friction.

463. In the previous example, when each power passes through a space of 1650 feet, what is the work (in horse-powers) done by each?

464. In the same example, if the vel. of the power is 3 feet a second, in what time will the men hoist the block 18 feet?

465. The wheel of the axle of a second-hand in a clock has sixty teeth. In order to combine this wheel with a set of toothed wheels so that the last wheel shall make one revolution in eight days, what proportion in the dimensions of wheels would you determine?

INCLINED PLANE.

(Advantage gained $= \frac{l}{h}$ or $\frac{b}{h}$, where l = length, b = base, and h = the height of the inclined plane.)

467. What weight can be supported on a plane by a force of 20 pounds acting parallel to the plane, if the ratio of the height to the length is one-fourth?

(*Solution:* The advantage gained by this inclined plane $= \frac{4}{1} = 4$. Hence $20 \cdot 4 = 80$ pounds, answer.)

468. What force acting parallel to the plane (or length of the incline) is required to support a weight of 1400 pounds on a plane that rises 2 in 7?

469. Find the inclination of a plane, if a force of 10 oz. acting parallel to the plane just moves a weight of 35 oz.

470. A plane rises $1\frac{1}{2}$ in $10\frac{1}{2}$. What force acting parallel to the plane will balance a weight of 10 pounds on the plane?

471. A plane rises 3 in 5. What force acting parallel to the base can support a weight of $133\frac{1}{3}$ pounds?

472. Find the weight that can be supported upon an inclined plane rising 15 in 25 by a force of 27 pounds parallel to the plane, one-ninth of the force being lost by friction.

473. Two planes having the same height are placed back to back, and two weights of 7 and 10 ounces connected by a string passing over the summit are balanced. Find the ratio of the lengths of the planes. (M.)

474. What weight can be supported on a plane by a force of 10 kilograms acting parallel to the plane, if the plane rises 2 meters in 9?

475. What force acting parallel to the plane is required to support a weight of 525 kilograms on a plane rising 1.5 meters in 10.5 meters?

476. Find the weight that can be supported upon an inclined plane rising 0.45 meters in 2.25 meters, by a force of 12 kilograms acting parallel to the incline.

477. A person with a lifting capacity of 56 pounds, wishes to raise a barrel of flour (196 pounds) into a wagon 4 feet high. How long a plank must he use?

THE SCREW.

(Advantage gained $= \frac{c}{d}$, where c = the circumference described by the power applied, and d = the pitch, that is, the distance between two consecutive threads)

480. A screw has seven threads to the inch. What pressure can be produced by a force of 10 pounds applied at the circumference, the diameter of which is 2 inches?

Solution: The circumference described by the power = 2 • (3 1416) = 6.2832 inches; the distance between the threads = $\frac{1}{8}$ inch. Hence the advantage gained = 6 2832 ÷ $\frac{1}{8}$ = 37.6992. Multiplying this by 10, the power applied, we have 376.992 pounds, answer.

481. What force must be applied to a circumference of 20 inches, if the resistance to be overcome is 100 pounds, and the pitch of the screw $\frac{2}{5}$ inch.?

482. What pressure is produced by a screw, if a power of 1 pound describe a revolution of 2½ feet whilst the screw moves through $\frac{1}{8}$ inch?

483. What must be the pitch of a screw if a power of 10 pounds, acting at the end of a lever 7 inches long (radius), exerts a pressure of 2640 pounds?

484 Any change upon the ratio between power and weight has what effect in the length of the lever to which the power is applied?

485. The pitch of a screw is 0.03 m.; a force of 5 kilos. acts at the end of a lever (radius) 0.35 m. long. What is the pressure exerted?

486. A screw having a head 12 inches in circumference is so formed that its point advances a quarter of an inch at each revolution. Find what force must be applied at the circumference of the head that the screw may produce a pressure of 144 pounds.

487. An endless screw, supposed to move without friction, has a crank 1½ feet long; its threads work in a wheel of 80 teeth, whose axle has a circumference of 1 foot; a rope winds around the axle, at the end of which hangs a weight of 7540 pounds. Find the power required to lift the weight

488. The lever of a differential screw (or Hunter's) is 35 inches long, fastened to the axis at its center, and worked by a power of 10 pounds at each end; the two pitches are respectively $\frac{1}{11}$ and $\frac{6}{11}$. Find the pressure exerted, the machine being supposed to run without friction.

THE PULLEY.

(Stiffness of ropes and weight of pulleys neglected.)

490. What is a fixed pulley, and what is meant by the "block"?

491. What is a movable pulley?

492. Describe and illustrate the use of a fixed pulley.

493. What is the equation of work in a single movable pulley?

494. What is the equation of work in a system of pulleys in which the same string passes round all the pulleys?

495. What is the equation of work in a system of pulleys in which each hangs by a separate string?

496. Find the weight that may be lifted by an arrangement of 3 movable pulleys, in which the same string passes round each pulley, the power applied being 20 pounds.

Solution: Advantage gained by each movable pulley = 2. Hence $(3 \cdot 2)\ 20 = 120$ pounds, answer.

497. Find the weight that can be raised by an arrangement of four fixed and three movable pulleys, in which the same string passes round all the pulleys, the power applied being 20 pounds. Make a drawing. (Advantage gained = 7.)

498. Find the power which will support a weight of 480 pounds by an arrangement of pulleys as in example 496.

499. A man weighing 150 pounds forces up a weight of

100 pounds by means of a fixed pulley over his head. Find his pressure on the floor.

500. What is the mechanical advantage of a system of 4 movable pulleys, each pulley hanging by a separate string? Explain.

501. A weight of 800 pounds is to be raised by means of a system of 3 pulleys hanging by separate strings. Find the power required.

502. In a system of one fixed and one movable pulley, what is the force with which a man pulls himself up, if he is suspended from the movable pulley, and raises himself by pulling at the free end of the string?

503. Explain by means of a diagram the action of the differential pulley.

504. Illustrate the general law of mechanical powers by means of the differential (or Weston's) pulley.

505. What is the power required to lift a weight of 1800 pounds by means of a differential pulley, the circumferences of the fixed pulleys being 19 and 20 inches respectively?

506. What is the power required to lower the above weight by the same differential pulley?

HYDROSTATICS.

510. Define hydrostatics.

511. What is a liquid?

512 What is meant by viscosity?

513. How do liquids differ from solids and gases?

514. What do you know concerning the surface of liquids at rest and that of liquids in motion?

515. What do you know concerning the shape and compressibility of liquids?

516. Define the term fluid. Distinguish between fluids, liquids, and gases.

TRANSMISSION OF PRESSURE—HYDROSTATIC PRESS.

517. State the law of the equal transmission of pressure in liquids. (Pascal's law.)

518. How do you find the advantage gained in a hydrostatic press?

519. The sectional area of the plunger (or large piston) in a hydrostatic press is 100 inches; that of the piston of the pump (or small piston) $= \frac{4}{5}$ inch., the pressure upon the piston being 300 pounds. Find the effect of the machine.

(In this machine the advantage gained by the water = $100 \div \frac{4}{5} = 125$, which multiplied by the power applied, 300 pounds, = 37500 pounds, answer.)

520. If the stroke of the pump piston in the previous example is 2½ inches, how far does the plunger move at every downward stroke of the piston?

521. How many downward strokes must the piston in ex. 520 make in order that the plunger may advance 2 inches?

522. A hydrostatic press is worked by a power of 30 pounds. The arm of the lever at which this power acts is six times as long as the arm at the end of which is the pump-piston. The cross-area of the latter is $\frac{1}{30}$ that of the plunger. Required the pressure transmitted to the plunger.

523. The diameter of the plunger in a hydrostatic press is 10 inches; that of the piston of the pump is ½ inch. The piston is fastened 1½ feet from the fulcrum of a lever of the second class 6 feet long. The power applied to the lever being 40 pounds, and the friction of the machine being equivalent to the loss of ¼ of the entire effect, find the available effect of the machine.

524. The sectional area of the plunger in a hydraulic press is 0.5 square meters, and that of the piston of the pump 0.0025 square meters. The pressure upon this piston is 120 kilograms. Find the entire effect of the machine.

525. The diameter of the plunger in a hydrostatic press is 0.25 m., that of the pump-piston 0.0125 m. This piston is fastened 0.3 m. from the fulcrum of a lever of the second class 2.7 m. long. The power applied being 30 kilos., find the theoretical effect of the machine?

526. By means of a pressure of 200 pounds on a pump-piston of ½ inch diameter, I wish to exert an effect of 28800 pounds. What must be the diameter of the plunger?

PRESSURE OF LIQUIDS ON THE BASE AND SIDES OF VESSELS.

(Remember: A cubic foot of water weighs nearly 62.5 pounds. A cubic inch of water weighs 0.03616898 pounds. A cubic centimeter of water weighs 1 gram.)

527. State the law regarding the pressure of liquids on the base of vessels.

528. A cubical vessel, whose edges are each 12 inches long, is filled with water. Find the pressure upon the bottom of the vessel.

529. The same vessel is filled with sulphuric acid, sp. gr. 1.85. Required the pressure of the acid upon the bottom of the vessel.

530. The same vessel is filled with water to the height of 6 inches. Find the pressure upon the bottom of the vessel.

531. A vessel 6 inches wide by 12 inches long and 24 inches high is filled with water. Required the pressure upon the base.

(The press. of liq. upon the base of vessels depends on the area of base into the vertical height of the liquid. Now, the area of the base of this vessel = 6.12 = 72 sq. inches, which multiplied by 24 inches = 1728 cubic inches = 1 cubic foot, the vertical pressure or weight of which is 62.5 pds., answer.)

532. The vessel in ex. 531 contains mercury, sp. gr. 13.6, but standing only 12 inches high. Required the pressure upon the base.

533. A vessel 12 inches high, 6 inches long and 4 inches wide, has a tube 12 inches high fitted into its neck. When vessel and tube are filled with water, the water in the tube is pressed upon by means of a piston with a force of 100 pounds

to the square inch. Required the entire pressure upon the base of the vessel.

534. Find the pressure upon the interior surface of a sphere of 4 feet diameter filled with water.

535. Find the weight of the water in the sphere of the preceding example.

536. A cylindrical vessel has a diameter of 4 inches, and is filled 13.75 inches high with water. Find the pressure upon the base of the vessel.

537. The preceding vessel contains nitric acid, sp. gr. 1.2, standing at the same height. Required the pressure upon the base of the vessel.

538. A barrel 3 feet long stands on one end, which has an area of 216 square inches and forms the base of the barrel. A vertical tube 5 ft. high is inserted in the other end of the barrel. Both, barrel and tube, are full of water. Required the pressure upon the base of the barrel.

539. I throw a block of wood into a pail filled with water; will it increase the pressure on the bottom of the pail? How will it affect the pressure when the pail is not quite full?

540. A cubical vessel, each edge 10 centimeters long, is filled with water. What is the pressure of the water upon the bottom of the vessel?

541. The vessel in ex. 540 is filled with sulph. acid, sp. gr. 1.85. Required the pressure upon the bottom of the vessel.

542. The vessel in ex. 540 contains water to the height of only 5 centimeters; required the pressure upon the bottom.

543. A vessel 20 centim. wide by 30 cent. long and ½ meter high is filled with water. Required the pressure upon the base.

544. Find the pressure exerted upon the base of the preceding vessel if the liquid be mercury, sp. g. 13.6?

545. A four-sided bottle 25 cent. high, each edge of the base being 10 cent. long, has a tube 50 centim. high inserted in its neck. The whole being filled with water, the water in the tube is pressed upon by a piston with a force of 10 grammes to the square centimeter. Required the pressure upon the base of the bottle.

546. A cylindrical vessel has a diameter of 10 centimeters, and is filled with water to the height of 20 centimeters. Find the pressure upon the bottom of the vessel.

547. Find the pressure upon the bottom of the preceding vessel filled to the same height with nitric acid, sp. gr. 1.2?

548. State the law of the pressure of liquids against the sides of vessels.

549. What is the pressure against each side of a cubical vessel, each edge of which is 1 ft. long, if the liquid stands inches high and has a sp. gr. of 1.25?

Solution.—The pressure of liquids upon the side of vessels containing them depends on the area in contact with the liquid *into* the vertical height from the center of area to the surface of the liquid. (This is only approximately correct.) 12 ins. length by 8 ins. height = 96 sq. ins. area; the height of liquid = 4 ins., and $96 \cdot 4 = 384$ cub. inches = $\frac{2}{9}$ cub. ft. If the liquid were water, this $\frac{2}{9}$ cub. ft. would exert a pressure = $(62.5).\frac{2}{9} = 14\frac{1}{9}$ pds.; but the liquid has a sp. gr. of 1.25; therefore $14\frac{1}{9} \cdot 1.25 = 17.6$ pds. = answer.

550. What is the pressure against a side of a cubical vessel filled with water, whose edges are each 1 foot long?

551. Required the pressure against each side of the preceding vessel if filled with a solution of potash, sp. 1.25.

552. Required the pressure against each side of the vessel in example 550 containing mercury 12 cen. high.

553. Required the pressure against the larger side of the vessel in Ex. 543.

554. A canal-lock is 30 feet wide. Required the pressure against it, if the height of the water on one side is 8 feet.

555. The side of a tank contains a rectangular aperture 9 inch. wide and 8 inch. high, which is closed by a vertical plate pressed against the aperture with a force of 200 pounds. Required the height above the center of the aperture, to which the tank can be filled with water.

556. What is the pressure upon the four vertical sides of a cube filled with water, whose edges have each a length of c?

557. What is the pressure upon the surfaces of the cube in ex. 556?

558. Required the pressure against one of the four sides of the cub. vessel in ex. 540.

559. Required the pressure against one of the sides of the same vessel if filled with sulph. acid, sp. gr. 1.85.

560. Required the pressure against one side of the bottle given in ex. 545.

561. Required the pressure against the side of the vessel in ex. 546.

COMMUNICATING VESSELS.

570. State the laws concerning liquids in communicating vessels.

571. One of the limbs of a U-shaped glass tube contains mercury (sp. gr. 13.58) standing 0.150 m. high; the other limb contains bromine to a height of 0.657 m.; both liquid columns are in equilibrium. Required the sp. gr. of bromine (water = 1). (0.150 : 0.657 :: x : 13.58, whence x = 3.1.)

572. Find the height of a column of water in one limb of a U-shaped tube, if it is in equilibrium with a column of mercury (sp. gr. 13.6) 0.025 m. high in the other limb.

573. One of the limbs of a U-shaped tube contains a liquid to the height of h, the other contains water to a height of $1\frac{1}{10}\,h$; both columns are in equilibrium. Required the specific gravity of the liquid.

UPWARD PRESSURE — FLOTATION.

577. State the law of the upward pressure of liquids on immersed bodies.

578. What is the "Principle of Archimedes?"

579. State what occurs—

(1) When the displaced liquid has the same weight as the immersed body;

(2) When it has less weight;

(3) When it has more weight.

580. What is required in order that a floating body be in equilibrium?

581. What is meant by the metacenter of a floating body?

582. Find the force required to support a cubic decimeter of platinum, sp. gr. 21, in mercury of sp. gr. 13.6.

(The force will be equal to the weight of the platinum diminished by the weight of a like volume of mercury. The weight of a decimeter of water=1 kil.; that of a decimeter of platinum=1.21=21 kil.; and the weight of a decimeter of mercury=1 . 13.6=13.6 kil. Hence, 21—13.6 =7.4 kil., answer.)

583. A body weighs in air 90 grams. It is 15 centim. long, 2 centim. wide and 3 centim. high; required its weight in water.

584. A body weighing 1000 pounds has a volume of 10 cubic feet, and is held suspended in water. Required—

(1) Its loss in water;

(2) The upward pressure against it;

(3) The force requisite to support it in the water.

585. What force is required to lift a man in water whose volume = 1.2 cubic ft., and who weighs 150 pds. in the air?

Solution.—His loss in water is 1.2 . 62.5=75 pds; hence, his weight in water=(150–75)=75 pounds. This is the force required to lift him in the water.

586. A ball 0.5 m. diameter weighs in air 200 grs. what will it weigh if suspended in water?

587. Find the weight of a leaden bullet suspended in water, whose diam. is 2 centim., 1 cubic centim. of lead weighing 11 grams.

588. Required: the weight of the preceding bullet suspended in an acid of sp. gr. 1.2. (Ask yourself first, whether in the acid the bullet will weigh less or more than it weighs in water.)

589. Required: the weight of the preceding bullet in alcohol of sp. gr. 0.95.

590. What is the weight of a floating body whose capacity is 600 cubic centimeters, and which enters in the water two-thirds of its volume?

591. What is the buoyancy of a cube each edge of which = 0.75 m., and a cubic meter of which weighs 110 kilos.?

592. A hollow sphere of brass whose exterior diameter = 0.5 m., is filled with air. The square decimeter of the sheet brass weighs 10 grams; the cubic decimeter (or liter) of air weighs 1.2932 grams; and the difference between the interior and exterior diameters is neglected. Required the buoyancy of the sphere. (*Solution.*—

Vol. of sphere = 98.175 c. c. of air; weight = 0.12696 grs.

Sheet-brass, surface = 0.7854 m.; weight = 78.54

78.66696 grs.

Subtracting this from 98.175 grs. (the weight of the water displaced when the sphere is totally immersed), we have (98.175) — (78.66696) = 19.50804 grs., buoyancy.)

593. A vertical tube of 10 centim. diameter is held closed at the lower end by a ground plate weighing 1 kilogram. What is the least depth to which the tube must be vertically immersed in water in order that the plate be held up by the upward pressure of the water?

594. Find the bearing capacity of a raft made of 20 pine logs, each log being 4 meters long with a diameter of 0.3 m., if one cubic meter of the wood weighs 900 kilos.

595. How many grams of lead must be placed within a cube of pine wood, whose edges are 10 centimeters each, so that the cube may float just beneath the surface of the water? (The weight of a cubic meter of the wood = 900 kilos.)

596. What force is necessary to hold a piece of platinum whose volume = 50 c c. suspended in mercury at O°C? (Specific gravity of platinum = 21.5; of mercury = 13 6.)

597. What force is required to support a cubic decimeter of lead (sp. gr. 11) in mercury at O°C?

598. A cube of lead, the side of which is 4 cent., is to be

supported in water by attaching it to a sphere of cork. What must be the diameter of the latter, the specific gravity of cork being 0.24, and that of lead being 11.35 ?

(The volume of the lead is 64 cubic centimeters; its weight in air is, therefore, $64 \cdot 11.35$, and its weight in water $64 \cdot 11.35 - 64 = 662.4$ grs.

If r be the radius of the sphere in centimeters, its volume in cubic centimeters will be $\frac{4 \pi r^3}{3}$, and its weight in grams is $\frac{4 \pi r^3 \cdot 0.24}{3}$. Now, as the weight of the displaced water is obviously $\frac{4}{3} \pi r^3$ in grams, there will be an upward buoyancy represented by $\frac{4 \pi r^3}{3} - \frac{4 \pi r^3 \cdot 0.24}{3} = \frac{4 \pi r^3 \cdot 0.76}{3}$, which must be equal to the weight of the lead; that is $\frac{4 \pi r^3 \cdot 0.76}{3} = 662.5$, from which $r = 5$ centim. 925, and the diameter = 11.85 centim.) (A)

SPECIFIC GRAVITY.

(*For Table of Specific Gravities see Appendix.*)

MEANS OF DETERMINING SPECIFIC GRAVITY.

OF SOLIDS—

I. *The Hydrostatic Balance.*—The body under examination is suspended below one of the pans of a balance, and its absolute gravity balanced by weights in the other pan. Next, the body is immersed in water, and equilibrium restored by placing weights upon the pan above the body. These additional weights are the weight of a like volume of water.

II. *Nicholson's Hydrometer* (or Areometer).—In order to sink the apparatus as far as a certain mark on the rod, place the substance together with sufficient weights in the dish. The weight of the apparatus + the substance + the weights = the weight of the displaced liquid. Next, remove the substance and replace it by weights, so that the apparatus sinks again as far as the mark. The weights that have replaced the body are its absolute gravity or weight. Now, remove these weights, place the body in the basket and immerse again. To sink the apparatus as far as the mark, additional weights must be placed upon the dish; these are equal to the loss of the body in water, that is, to the weight of a like volume of water.

III. *The Pycnometer.*—Fill flask with water or any other suitable liquid, to the stopper, and weigh (the weight of the flask is balanced by a counterpoise). Next, place the body by the side of it, and weigh both; by subtraction, find the absolute gravity of the body. Then immerse the body in the liquid and replace the stopper. Dry carefully and weigh again. To restore equilibrium weights must be added; these weights are the loss of the body. This method and the following are specially adapted to bodies in grains or fragments.

IV. *A Thousand-Grain Flask.* — Fill the flask partly with water and weigh (the weight of the flask is balanced by a counterpoise). Next, immerse the grains or fragments until the liquid rises to the mark. Weigh again; by subtraction find the absolute gravity of the substance. The difference between 1000 and the weight of the water employed = the weight of the volume of water displaced by the substance.

When the body under examination has less specific gravity than water, the following method may be applied in place of Nicholson's hydrometer: Attach the body to a heavy mass whose weight, both in air and water, is known. Immerse both in water, and find the loss of both bodies. From this loss subtract the loss of the heavy mass alone; the remainder will be the loss of the body under examination, that is, the weight of a like volume of water. Dividing the weight in air of the body by this remainder, the specific gravity is obtained.

OF LIQUIDS—

V. *The Hydrostatic Balance.* Find first, according to I, the loss in water of e. g. a cube of brass; next, find the loss of the same body in the liquid under examination.

VI. *Nicholson's Areometer or Hydrometer.* Immerse the apparatus first in water, then in the liquid under examination. The additional weights required to sink it in water as far as the mark + the weight of the apparatus = the weight of volume of water. The additional weights required to sink it in the liquid as far as the mark + weight of apparatus = the weight of a like volume of the liquid.

VII. *A Specific Gravity Flask* capable of containing some determined quantity of water, such as 100 grs. or 1000 grs. After balancing it on a scale fill it with the liquid under examination up to the mark; the weights required to balance the liquid = its absolute gravity. Next divide by 100 or 1000, according to the capacity of the flask; the quotient = the specific gravity of the liquid.

VIII. *Hydrometers.* The volumes displaced by the same body immersed in different liquids are inversely as the specific gravities of the liquids. Suppose that the number 100 indicates the point to which the hydrometer sinks in water, and that it sinks in another liquid to 125, that is, 25 degrees above 100, each degree being 0.01. Now, these volumes displaced must

have equal weight; and as, therefore, the volume of the lighter liquid must be greater than the volume of the heavier, both volumes must be inversely as the specific gravity of the liquids. Hence: Specific gravity of the liquid is to 1 (sp. gr. of water) as 100 is to 125; whnce the sp. gr. of the liquid is found to be 0.8.

OF GASES.—

IX. *A Globe of Glass* provided with a stop-cock. Suspend the globe (filled with air) from one of the scales of a balance; establish equilibrium by placing a weight on the other scale. Next exhaust the air from the globe, and weigh again; the weight now found is that of the globe. The difference between the two weights = the weight of the contained air. Now, let the gas under examination rush into the globe, and weigh again; the additional weight obtained = the weight of a like volume of the gas. Divide this by the weight of the air; the quotient = the specific gravity of the gas.

600. Define Specific Gravity.

601. How may the specific gravity of a body be found?

602. Describe the process of determining the sp. gr. of a solid by means of the hydrostatic balance.

603. A piece of platinum weighing 1 kil. loses 46½ grams when weighed in water. Required its specific gravity?

(The weight in air of a substance divided by its loss in water=its sp. gr. Now $\frac{1000}{46.5} = 21.5$ sp. gr. of the platinum.)

604. A piece of iron weighing 2 kil. weighs in water 1.75 kil.; find its specific gravity.

605. A piece of sandstone weighing 1.2 kil. weighs in water 0.7 kil.; required: its specific gravity.

606. A piece of talc weighs 78 grams; it weighs in water 48 grams.; find its specific gravity.

607. Describe the process of determining the sp. gr. of a solid by means of Nicholson's hydrometer or areometer.

608. A piece of sulphur is placed upon the dish of a Nicholson hydrometer; 20 grams. are required to sink the hydro-

meter down to the mark; and afterwards 3 grs. to take the place of the sulphur. When it is put in the basket and immersed, 21.5 grams must be on the dish. Required the specific gravity of the sulphur.

609. With 31 grs. on the plate, a hydrometer sinks to the same mark as with 26.5 grs. and a piece of phosphorus on the plate. But when the phosphorus is placed in the basket, 29 grs. must be laid on the plate to sink the hydrometer to the same mark. Required the sp. gr. of the phosphorus.

610. Describe the process of determining the specific gravity of a solid by means of the pycnometer.

611. A flask filled with water to the stopper weighed 800 grams. When it was weighed with the fragments of the mineral pyrolusite beside it, both weighed 810 grams. After the mineral was put into the flask, a weight of 2 grams was required to restore equilibrium. Find the sp. gr. of the mineral.

612. A flask filled with water to the stopper weighed 548 grams. When weighed with fragments of a meteorite ("meteoric dust") beside it, both weighed 560 grams. After the mineral was put into the flask, a weight of 1½ grs. had to be added to restore equilibrium. Required the specific gravity of the substance.

613. A flask filled to the stopper with oil of specific gravity 0.95, weighed 760 grams; together with a quantity of common salt (in grains) both weighed 764.2 grams; but when the salt was immersed in the oil, a weight of 1.9 grs. had to be added to restore equilibrium. Required the specific gravity of common salt, water being the standard.

614. A flask filled to the stopper with petroleum (sp gr 0.84) weighed 300 grs. Grains of blue vitriol weighing 6 grs. in air were then immersed; both together weighed 303.7 grs. Required the specific gravity of blue vitriol (water being the standard).

615. Describe the process of determining the sp. gr. of solids by means of a flask holding a thousand grams or a thousand grains.

616. A thousand-gram flask containing 900 grams of water, besides fragments of the mineral Andalusite, was found to weigh 1200 grs. Required the sp. gr. of Andalusite.

(Weight of mineral=(1200—900)=300 grs,; weight of a like bulk of water=(1000—900)=100. Now $\frac{300}{100}$=3. Ans.)

617. When sand was introduced into a thousand-gram flask containing 800 grs. of water, the water rose up to the mark, and both together were found to weigh 1220 grs. Required the specific gravity of the sand.

618. Grains of Platinum were put into a thousand-gram flask containing 990 grams of water, until the water rose to the mark; both together then were found to weigh 1205 grams. Find the specific gravity of the platinum.

619. A thousand-gram flask contained 980 grams of water. Metallic arsenic (in the form of grains) was then introduced; the water rose to the mark, and both substances together were found to weigh 1092 grs. Required the specific gravity of metallic arsenic.

620. A 1000 gr. flask contained 984 grs. of alcohol (sp. gr. 0.8). A piece of maple wood was introduced; the alcohol rose to the mark; both together weighed 1002 grams. Find the specific gravity of maple wood. Ans. 0.9.

621. A hundred-gram flask was filled with 85 grams of naptha (sp. gr. 0.7). A piece of sodium was immersed in the naphtha, after which the liquid rose to the mark. Both substances together weighed 106 grams. Find the specific gravity of sodium.

622. A piece of wrought iron whose volume is 108 cubic inches, weighs 30.5 pounds. What is its specific gravity?

Solution.—The weight of a like bulk of water (or the loss in water) evidently = the weight of 108 cubic inches of water, $= \frac{108}{1728}$ of 62.5 = 3.9 pounds. Now, $\frac{30.5}{3.9} = 7.8$, answer.

623. Ten cubic centimeters of copper weigh 89 grams. Find the specific gravity of copper.

624. A piece of marble whose volume = 15 cubic centimeters weighs 42 grs. What is the specific gravity of marble?

625. A diamond weighs 0.35 gram, and has a volume of 0.1 c. c. Find its specific gravity.

626. A piece of platinum weighing 1 kilo. loses in water 47.4 grs. Find its specific gravity.

627. A piece of graphite weighing 10 grams loses in water 4 grams; find its specific gravity.

628. A piece of ice weighs 11.6 grams; it weighs 1.6 grs. in absolute alcohol (specific gravity 0.79, temp. of 0° C). Required its specific gravity.

629. What is the volume of a piece of zinc whose weight in air is 865.2 grs., its specific gravity being 7.21?

Solution. — $\frac{865.2}{7.21} = 120$ grs. loss in water, or weight of a like volume of water. Now, 1 gram of water has a volume = 1 c. c.; hence the volume of 120 grs. = 120 c. c., answer.

630. What is the volume of a piece of glass that weighs in air 60 grams, and has a specific gravity of 3?

631. Find the volume of 100 kilos. of silver.

632. Required the length of the edge of a cube of iron (sp. gr. 8) weighing 1 kilo.

633. A freight-car 22 feet long by 5¼ feet wide may be loaded 2 feet high with coal of specific gravity 1.4. What weight will it carry?

634. A square meter of sheet iron (specific gravity 7.6) weighs 38 kilos. Required its thickness.

635. If 100 pds. of cast iron are weighed suspended in water, what will be the loss of weight?

Solution.—Since $\frac{\text{weight in air}}{\text{loss in water}} = \text{sp. gr.}$, we have $\frac{\text{wt. in air}}{\text{sp. gr.}}$ =loss in water. Now, $\frac{100}{7.2}=13.88$, answer.

636. What will be the loss of weight of 10 pds. of limestone when weighed suspended in water?

637. Find the weight in sulph. acid (sp. gr. 1.8) of a piece of lead (sp. g. 11) weighing 143 grams.

Solution.—The weight of the lead in sulph. acid is found by subtracting its loss in sulph. acid from its weight in air. But to find the loss in sulph. acid we must first ascertain its loss in water; that is, the weight of a like volume of water. To do this, we have $\frac{143}{11}=13$, weight of a like vol. of water, and $13 \cdot (1.8)=23.4$ weight of a like volume of acid, or loss of the lead in the acid. Now, $143-(23.4)=119.6$, grams, answer.

638. Required: the loss of weight of 10 kilogs. of coal weighed suspended in water.

639. A body weighing 18 ozs, and having a sp. gr. of 0.8, is fastened by a thread to the bottom of a vessel; when water is poured in so as to completely cover the body, to what tension is the thread exposed?

640. Find the loss of weight of 100 kil. of sandstone weighed suspended in water.

641. A solid weighing 695 grs. in air loses in water 83 grs. Required its weight in alcohol (sp. gr. 0.7).

642. A piece of steel loses 10 grams in water. Required its weight in air.

643. A piece of sand rock loses 5 pounds in water; find its weight in air.

644. A piece of heavy spar (sp. gr. 4.5) loses 5 gr. in water; find its weight in air.

645. A piece of ivory (sp. gr. 1.92) loses 5 grams in alcohol (sp. gr. 0.8); find its weight in air.

646. A piece of ice loses 25 grams in alcohol (sp. gr. 0.8); find its weight in air.

647. A piece of flint glass (sp. gr. 3.5) weighed in water 102 grams.; find its weight in air.

648. A piece of quartz (sp. gr. 2.6) weighed in water 17 grs.; find its weight in air.

649. A platinum sphere 3 cen. in diameter is suspended to to the beam of a very accurate balance, and is completely immersed in mercury. It is exactly couterbalanced by a copper cylinder of the same diameter completely immersed in water. Required the height of the cylinder (sp. gr. of mercury 13.6, of copper 8.8, and of platinum 21.5). (A.)

650. State the process for finding the specific gravity of bodies floating on water (when Nich. hydrometer is not employed).

651. A piece of cork weighs 8 grams in air; a piece of lead to which it is attached weighs 22 grams in air, and the weight in water of both bodies is 4 grs. (sp. gr. of lead = 11). Find the specific gravity of the cork.

652. A piece of wood weighed 10 grams in air, and was then attached to a piece of lead whose loss in water = 2.5 grams. Both being weighed together in water were found to lose 32.5 grs. (that is, to displace a volume of water weighing 32.5 grs.) Find the specific gravity of the wood.

(Subtracting the loss of the lead from the loss of both, we have 32.5—(2.5)=30 grs., the weight of a vol. of water equal to the volume of the wood. Now, $10 \div 30 = \frac{1}{3}$, answer.

653. A piece of maple wood weighs 18 grs. in air; when attached to a piece of lead weighing 33 grs. in air, both were found to lose 23 grs. in water. Required, the specific gravity of maple wood.

654. A piece of poplar wood weighed 11.2 grs. in air; it was fastened to a piece of iron (sp. gr. 8) whose vol. = 3 c. c. Both together were found to lose in water 31 grs. Required, the specific gravity of poplar wood.

655. When a brass ball (sp. gr. 8.5) weighing 17 grs. was fastened to a piece of wax weighing 1.92 grs., and both were immersed, their combined weight in water was 14.92 grs. Required, the specific gravity of the wax.

656. A body weighing 7 grs. has tied to it a metallic weight of 16 grs. Both together weigh in water 10.4 grs., the metal alone weighing 14.8 grs. in water. Required, the specific gravity of the body.

657. What is the weight of 1000 c. c. of sandstone?

Solution.—The weight of 1000 c. c. of water = 1000 grs. The specific gravity of sandstone = 2.4; hence, the weight of 1000 c. c. of sandstone = 1000 (2.4) = 2400 grs.

658. What is the weight of 1 cubic meter of bitum. coal?

659. What is the weight of a cubic foot of lead?

660. The weight of a cubic decimeter of a body expressed in kilograms is also its specific weight. Explain.

661. A leaden rod has 1 square centimeter sectional area, and a length of 10 meters. Find its weight.

662. A substance whose volume = 1000 c. c. weighs *n* kilogr. Find its specific gravity.

663. What is the weight of a wall of sandstone (sp. gr. 2.5) 10 meters long, 2 meters high by 0.4 m. thick (the weight of the mortar is neglected)?

664. Find the weight of a bar of sulphur 4 centim. diameter and 10 centim. long.

665. In 60 cubic decimeters of rock whose average sp. gr. is 1.5 there are 45 cubic decimeters of a substance whose sp. gr. = 1.3. Find the sp. gr. of the remainder of the rock.

666. Find the weight of a sphere of lead of 1 meter radius.

(The vol. of the sphere $= \frac{4\,\pi\,r^3}{3} = \frac{4 \cdot 3.1416 \cdot 1^3}{3} = 4.189$ cub. m. An equal vol. of water weighs 4189 kils.; an equal vol. of lead, therefore, weighs $4189 \cdot 11 = 46079$ kils.)

667. Gold of sp. gr. 19.362 has been made into leaves of 0.0001 of a millimeter in thickness; what surface can be covered with 10 grams of gold? (C. & M.)

(Let x be the surface to be covered, and let it be a rectangular parallelopiped whose height = 0 m. 0000001, and whose volume = x (0.0000001). Now, 10 grs. = x (0.0000001) 19.362, whence $x = \frac{10}{0.0000001 \cdot 19.362} = \frac{100\,000\,000\,000}{19.362} =$ 5164755 sq. centim. = 516 sq. m., 47 sq. decim., 55 sq. centim.)

ALLOYS.

(In these mixtures, or in the combination of alloys, no shrinkage of volume is supposed to occur.)

670. The specific gravity of zinc being 7 and that of copper 9, what weight of each metal must be taken to form 50 grams of an alloy having the specific gravity of 8.2; it being assumed that the volume of the alloy is exactly the sum of the alloyed metals? (A.)

Solution.—Let x = the weight of the zinc, and y that of the copper. Then $x+y = 50$, and as the loss of the zinc together with the loss of the copper constitute the loss of the whole, we have $\frac{x}{7} \cdot \frac{1}{9} = \frac{50}{8.2}$. From both equations we obtain $x = 17.07$, and $y = 32.93$.

671. Find the specific gravity of an alloy composed of 5 pounds of tin and 8 pounds of copper.

Solution.—Let x = the specific gravity of the alloy. Now, $\frac{5}{7.3}$ = the loss of tin in water, and $\frac{8}{8.8}$ that of copper. Hence the equation $\frac{5}{7.3} + \frac{8}{8.8} = \frac{13}{x}$, whence $x = 8.15$ sp. gr. of alloy.

672. A certain kind of brass contains 75 per cent. of copper and 25 per cent. of zinc (sp. gr. as in 670). Find its specific gravity.

673. An alloy is composed of 6 parts of weight of copper, 3 parts of zinc, 0.5 parts of lead and 0.1 part of tin. Find its specific gravity. (Sp. gr. of metals = 9, 7, 11, 7, respectively.)

674. How much copper (sp. gr. 8.8) must be combined with 6 pds. of tin (sp. gr. 7.3), if the alloy is to have a sp. gr. of 8?

675. How much gold must be added to 3 pounds of silver to make an alloy of specific gravity 15?

676. I wish to obtain brass of 8.5 specific gravity. Find the percentage of copper and zinc required (sp. gr. as in table).

677. A nugget of gold quartz weighed 3 oz. in air, and lost ½ oz. when weighed suspended in water. Required the weight of gold in the nugget.

(Let x = the weight of gold and 3—x the weight of quartz.)

678. What is the specific gravity of sulphuric acid that has been obtained by mixing 7 pounds of sulph. acid of specific gravity of 1.8 with 3 pounds of specific gravity 1.5?

679. How much antimony must be added to 10 pounds of lead in order that the alloy may have a sp. gr. of 10.5?

680. An alloy composed of lead and tin weighs in air 30 ozs., and loses 3.6 ozs. when weighed in water; how much lead and tin does it contain?

SPECIFIC GRAVITY OF LIQUIDS.

682. A 1000-grain flask holds 2966 grains of bromine, 1848 grains sulphuric acid, 13590 grains of mercury, 718 grains of ether. Required, the sp. gr. of these substances.

683. A platinum cube, suspended in water, loses 2 grains; if suspended in mercury, it loses 27.2 grains. Find the specific gravity of mercury.

684. A flask weighing 20 grams weighs, when filled with water, 60 grams; when filled with sulphuric acid, 90 grams. Required, the specific gravity of the acid.

685. A flask weighing 30 grams weighs, when filled with water, 71 grams; when filled with another liquid, 55.83 grams. Required, the sp. gr. of the liquid.

686. A glass ball loses in water 8.6 grams; in oil, 8.17 grams. What is the specific gravity of the oil?

687. A heavy body loses in water 11 grs.; in nitric acid, 17 grs. Find the specific gravity of the acid.

688. What will the body in the previous example lose in muriatic acid, sp. gr. 1.15?

689. A man weighs 150 pounds, and has a sp. gr of 1.08. Required, his weight in ocean water (sp. gr. 1.03).

690. A body loses 25 grs. in water, 18 grs. in oil, and 16 grs. in alcohol. Required, the sp. gr. of the oil and alcohol.

691. A body weighs 2300 grains in air, 1100 grains in water, and 1300 grains in spirit. What is the specific gravity of the spirit? (S. K.)

692. The specific densities of the upper and lower of two fluids that do not mix are 0.9 and 1.1; the upper fluid is 4 inch. deep; a cube with an edge of 1 ft. and sp. gr. 0.75 floats in the liquids; how much of it is immersed? (S. K.)

693. A wooden block floating on water has one-half of its volume immersed; when floating on alcohol it displaces five-eighths of its volume. What is the sp. gr. of the alcohol?

(Since a floating body displaces its own weight of the liquid in which it floats, the weight of ½ vol. of water = the weight of ⅝ vol. of alcohol. Now the densities or specific gravities of two liquids are to each other inversely as their volumes of equal weight; therefore the specific gravity of water, 1, is to x, the specific gravity of alcohol, as ⅝ is to ½; whence x = 0.8.)

694. A weighted test-tube floats vertically in water. Degrees of equal parts are indicated upon it, of which it displaces 30¾ in water, and 30 in milk. Required the sp. gr of the milk.

695. A hydrometer displaces 14.2 parts of water, and 20 equal parts of ether. What is the sp. gr. of the latter?

696. A hydrometer displaces 28 parts in glycerine, and 35 equal parts in water. Required, the sp. gr. of the glycerine.

697. A hydrometer displaces in water a volume = v; in sulphuric acid, a volume = $\frac{4}{7}$ v. Required, the specific gravity of the acid.

698. A hydrometer displaces in water a volume = v; in oil, a volume = $\frac{10}{9}$ v. Required, the sp. gr. of the oil.

699. A hydrometer displaces in four different liquids, respectively, a volume = 1, 1.1, 1.2, 1.3. The liquid third in order being water (s. g.=1), find sp. gr. of the other liquids.

700. What volume is occupied by 6¼ pounds of sulphuric acid (sp. gr. 1.83)?

701. What is the volume occupied by 1 kilogram of mercury?

702. A bottle holds two pounds of water; how much ether, sp. gr. 0.7, will it hold?

703. A flask holds 500 grams of nitric acid (sp. gr. 1.5), how many grams of muriatic acid (sp. gr. 1.2) will it hold?

704. A graduated test-glass that contained 30 c. c. of sulphuric acid is to be filled with a like weight of water; how many c. c. of water must be put in?

705. How would you graduate a hydrometer for ascertaining the strength of alcohol?

706. How would you graduate a hydrometer for ascertaining the specific gravity of liquids heavier than water?

SPECIFIC GRAVITY OF GASES.

(In each example the weighings are supposed to have been taken at the same temperature and barometric pressure. The weight of 1 liter (= 1 cubic decimeter) of dry air at a temp. of 0°C, and under an atm. pressure of 760 mm. for latitude 45° at the level of the ocean = 1.292754 grams.)

710. A glass globe, when filled with atmospheric air, weighed 50.56 grams; when deprived of air it weighed 50.16 grams; when filled with illuminating gas it weighed 50.4 grs. Find the specific gravity of the gas.

711. The same globe, when filled with oxygen, weighed 50.6024 grs. What is the specific gravity of oxygen?

712. The same globe, when filled with hydrogen, weighed 50.18772 grs. Find the specific gravity of hydrogen?

713. The same globe, when filled with carbonic acid gas, was found to weigh 50.772 grs. Find the sp. gr. of the gas.

714. A globe deprived of air weighed 36.16 grams; when filled with dry air at a temp. of 0°C, and with the barometer

at 760 m. m., it weighed 36.66 grs.; when filled with distilled water of 4°C temperature, it weighed 422.91 grs. Find the specific gravity of water (air = 1).

715. From the preceding example, find the specific gravity of air (water = 1).

716. What is the weight of a liter of chlorine gas (sp. gr. 2.46) at 0°C, and 760 mm. atm. pressure, where a liter of air under the same conditions weighs 1.29 grs.?

717. Under the same conditions as in previous example what will be the weight of a liter of hydrogen?

718. What volume does 1 gram of hydrogen occupy (same conditions as in example 716)?

719. Find the weight of illuminating gas contained in a cylindric gasometer 15 meters diameter and 10 meters high, where a liter of air weighs 1.29 grams.

HYDRODYNAMICS OR HYDRAULICS.

(In these examples, the height of liquids is supposed to remain the same, unless otherwise indicated; and the coefficients of efflux and contraction may be omitted. In formula $v = \sqrt{2gh}$, take $g = 32$ feet, or 10 meters.)

721. Define hydrodynamics, or hydraulics.

722. What is the law of the velocity of liquids issuing from small orifices?

723. How do you find the volume of liquids issuing from narrow orifices?

724. Water issues from an aperture at the base of a vessel filled with water 16 feet high; find the velocity of the stream?

($v = \sqrt{2gh} = \sqrt{64.16} = \sqrt{1024} = 32$ feet, answer.)

725. The aperture at the bottom of a tank is 9 ft. beneath the surface of the water in the tank. Find vel. of the stream.

726. Find the velocity of a stream issuing from the base of a vessel filled with water 5 meters high.

727. A reservoir 7 meters wide and 3 meters deep is always kept full, and contains 84,000 kils. Find the velocity of a stream issuing from the base of the reservoir. (g.=9.8 m.)

728. The water in a vessel stands 18 feet high. What is the velocity of a stream issuing from a narrow aperture 9 feet above the base; and how far from the base of the vessel, horizontally, will it strike the ground?

729. A stream issuing from an orifice at the base of a vessel is to have a velocity of 36 feet. How high above the orifice must be the surface of the liquid?

730. A stream of liquid flows from the base of a vessel, and is to have a vel. of 5 meters. How high above the orifice must the surface of the liquid be kept?

731. Compare with each other the velocities of water issuing from two orifices in a constantly replenished vessel, one orifice being at the base, the other 16 feet above it and 9 feet below the surface of the water.

732. Compare the velocities of water flowing from three orifices in a replenished vessel; the first orifice is at the base of the vessel; the second is 2 meters above the first; the third 3 meters above the second and 5 meters below the surface of the water.

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733. How much water flows in a second from an orifice one inch wide at the bottom of a vessel, the water in the vessel always standing 9 feet high?

(Area of orifice • time • velocity = volume discharged. Now, 1 sq. inch = $\frac{1}{144}$ sq. foot; therefore, $\frac{1}{144}$ • 1 sec. • $\sqrt{2g.9}$ = volume, $\frac{1}{144}\sqrt{576}$ = v, whence v = $\frac{24}{144}$ = $\frac{1}{6}$ c. ft., ans.)

734. What quantity of potash (sp. gr. 1.2) will flow from the preceding vessel, the other conditions being as in the preceding example?

735. Find the quantity of water per hour that flows from an orifice ¼ of an inch diam. in the side of a vessel, the surface of water being 0.81 feet above the center of the aperture.

736. An aperture in the base of a vessel is 1 centim. square; the water in the vessel stands 1 meter high. Find the quantity of water discharged through the aperture in half an hour.

737. Find the weight of brine, sp. gr. 1.08, discharged in half an hour; other conditions the same as in example 736.

738. The aperture in the side of a vessel has an area of ½ inch; the quantity of water to be discharged per hour is 6250 pounds. Find the height at which the water must remain above the aperture during that time.

739. What is the pressure that must be exerted upon a column of water 2 meters high, in order that a vel. of 10 m. may be produced at its base? (g = 10 m.)

Solution.—$10 = \sqrt{2gh}$; hence, $10^2 = 2gh$, and $\frac{10^2}{2g} = h = 5$ m. = 500 cen. But as the actual height is only 200 cen. the additional pressure must be as great as a column of 300 cen. is heavy, or 300 grams for every □ cen.

740. What pressure must be added to a column of water 1 meter high in order that a velocity of 10 meters may be produced at the base?

741. Find the quantity of water flowing per minute from a vessel in which the surface of liquid is constantly 1 meter above an orifice whose area = 0.0075 meter.

742. How far below the surface of water must an orifice 1 centimeter square be placed in order that 300 liters shall be discharged per minute?

743. In what time will 72 gallons of water flow through an orifice, 1 inch in area, at the base of a vessel in which the liquid always stands 9 feet high?

744. In what time will 1000 liters of water flow through an orifice whose area = 2 square centim., which is at the base of a column of water 5 meters high?

745. In what time will a vessel filled with water be emptied by means of an aperture at the base, having an area of 1 sq. centim., if the vessel is 80 cen. high, and if the area of its base = 200 sq. centim. (Coeff. of efflux = 0.6)?

(16000 c. c. = x . 1 (0.6) . $\frac{1}{2}\sqrt{2gh}$; 16000 c. c. = (0.6) x . $\frac{1}{2}\sqrt{2(1000)}$. 80; whence x = 133 sec. answer.)

746. If a filled water tank is emptied in $\frac{1}{2}$ hour by means of an aperture at the base, in what time will it be emptied when the orifice has twice the area?

747. Find the time required to empty a cylindrical vessel filled with water, having a diameter of 1.25 feet, a height of 2.25 feet, and an orifice at the base of $\frac{1}{4}$ square inch area. (Coefll. of efflux 0.6)?

748. In what time will a filled Mariotte's flask be emptied if its diameter = 4 inch., its height 8 inch., and the area of the orifice at the base = $\frac{1}{4}$ square inch?

749. What is the shortest time in which a pond of 5 m. depth, 15 m. length and 10 m. breadth is emptied by means of a gate 1 m. high and 2 m. broad (Coeff. of contraction = 0.7; coeff. of efflux = 0.6)?

AEROSTATICS AND AERODYNAMICS (PNEUMATICS).

(Take the pressure of 1 atmosphere = 15 pounds to the square inch, the barometer at 30 inch; or 1033 grams to the square centimeter, the barometer at 0.76 meter.)

752. Define aerostatics and aerodynamics.

753. Mention the characteristics of aeriform fluids.

754. What is the form of the earth's atmosphere?

755. I give you a pop-gun, a bottle of soda-water, and a bottle filled with illuminating gas. What characteristics of aeriform bodies do these substances illustrate?

756. Give the composition of air, by volume and weight.

757. What is meant by a pressure of one atmosphere?

758. How far below the level of the sea will a diver be subjected to a pressure of 10 atmospheres? (Take the specific gravity of ocean water = 1.)

759. Find the total atmospheric pressure upon a man whose surface is 15 square feet.

760. Find the atmospheric pressure upon the entire surface of a cube whose edges are each 0.1 m long.

761. Find the atmospheric pressure upon a soap bubble whose diameter is 4 inches.

762. Find the atmospheric pressure upon a soap bubble whose diameter is 5 cent.

763. The piston of a steam engine has a diameter of 10 inches, and moves by a pressure of steam of 4 atmospheres. Find the amount of this pressure on the piston.

764. The cylinder of a steam engine has a piston of 20 cent. diameter, which is moved by steam of a pressure of 5 atmospheres. Find the amount of this pressure on the piston.

765. Find the side of a square subjected to the same amount of pressure as the piston in the preceding example.

766. A boiler 4 meters long and 1 m. in diameter, is subjected to a pressure of 10 atmospheres to the square cent. Find the amount of pressure upon its inner surface (thickness of the sides disregarded).

767. A boiler has a circular aperture of 0.1 m. diameter which is covered by a plate. Whenever the pressure of the steam in the boiler exceeds 2 atmospheres it raises the plate. Find the weight of the plate.

768. Of three columns of water, one is 357 feet high, the second 306 feet, and the third one 30 feet. Find the pressure of each expressed in atmospheres.

769. Find the pressure (in atmospheres) exerted by a column of water 76 meters high.

770. If the atmospheric pressure in a certain locality supports a column of water 30 feet high, what will be the height of a column of mercury supported by atmospheric pressure in the same locality and at the same time?

771. A pressure gauge was applied to the air vessel of a fire engine. When the men were doing their best it was observed that the index showed 45 pounds per square inch as the maximum. What height would the water have in a vertical column with such a pressure? and why does the jet from the fire engine fail to reach that height when worked at the 45 pound pressure?

772. Find the height of mercury, as in example 770, when the column of water is 0.68 meter high.

773. With conditions the same as in 770, what would be the height of a column of sulphuric acid (sp. gr. 1.875)?

774. With conditions the same as in ex. 772, what would be the height of a column of bromine (sp. gr. 3)?

775. With conditions the same as in ex. 770, find the height of a column of alcohol, sp. gr. 0.8.

776. Find the specific gravity of a solution standing 36 feet high where the mercurial column supported by the atmosphere = 28.6 inches.

777. The specific gravity of air being 0.0013, what is the theoretical height of a column of air that supports a column of mercury 760 millimeters high?

778. What are the pressures of air on a square centimeter of surface, where the mercury stands respectively 700, 600, 500, 50 and 1 m. m. high?

BAROMETER.

780. What is a barometer?

781. Describe the cistern-barometer.

782. Describe the syphon-barometer; and explain its advantage over the cistern-barometer.

783. Describe the aneroid barometer.

784. State the three most important barometric corrections

785. The readings of a barometer suspended within a room are the same as when it is suspended out of doors. Explain

786. What are the relations between the barometer and the weather?

787. The mercurial column in a barometer has a diameter of 0.008 m.; the mercury in the cistern one of 0.04 m. When the mercury in the tube rises 3 m. m., how much will the surface of the mercury in the cistern sink?

788. Supposing the density of the atmosphere to be uniform, and the barometer to stand 30 inch. at the level of the sea, what would be the height of the atmosphere (sp. gr. of air $= \frac{1}{770}$)?

789. A barometer was filled with impure mercury of specific gravity 13. Find its height at the sea level, expressed in m. m.

790. Mercury was poured into a barometer tube until the tube still contained 15 c. c. of air of the ordinary atmospheric pressure. The tube was then inverted in a mercury bath; the air now occupied a space of 25 c. c., and the column of mercury stood 302 mm. high. What was the pressure of the atmosphere? (A.)

(Let $x =$ the amount of this pressure. The pressure of the air in the upper part of the tube $= \frac{15}{25} x$, which, added to 302 mm., will be the pressure exerted within the tube upon the surface of the mercury in the bath, and is equal to the pressure of the atmosphere. That is: $\frac{15}{25} x + 302 = x$, whence $x =$ 755 mm., answer.)

791. A barometer tube was filled with mercury and inverted in a cistern filled with mercury. Then 10 c. c. of atmospheric air were admitted into the tube, and there occupied a space of 30 c. c., the mercury standing 500 mm. high Find the pressure of the atmosphere.

MARIOTTE'S LAW.

($V : V' :: P' : P$, whence formula $P' = \frac{PV}{V'}$, in which $V =$ the volume of gas, and P its pressure; V' the volume of the same quantity of gas subjected to pressure P'.)

794. State Mariotte's Law (or Boyle's), and its corollary.

795. How may Mariotte's law be proved experimentally?

796. The short limb of a bent glass tube (Mariotte's tube) is 4 inches long and closed at its end. To what height must mercury be poured through the open end of the long limb so as to compress the air in the short limb into a height of 3 inches, the barometer standing at 29 inches?

($V : V' :: P' : P$, or $4 : 3 :: x : 29$, whence $x = 38\frac{2}{3}$ inches. From this subtract 29; to the remainder, $9\frac{2}{3}$ inches, add 1 inch, which takes the place of 1 inch of air. Answer $= 10\frac{2}{3}$ inches.)

797. Find the required height of mercury to compress the air in the preceding example into a space of 2 inches.

798. With the barometer at 750 mm., and the short limb 100 mm. long, find how high the mercury must stand in the long limb of a Mariotte's tube to compress the air in the short limb into 75 mm.

799. An inverted tumbler is placed on a surface of water in such a manner that its brim is just beneath the surface. It is then pushed down vertically 17 inches. Find the amount of compression of the air confined in the tumbler.

800. At what pressure will a liter of hydrogen gas, sp. gr. $\frac{1}{14.5}$, have the same weight as a liter of air at a pressure of 760 mm. (temperature disregarded)?

801. To what volume would a liter of hydrogen at 760 mm. be reduced, were its pressure increased until its density = that of atmospheric air at a pressure of 760 mm.?

802. If a liter of air weighs 1.3 grams at 760 mm., what will a liter of air weigh at a pressure of 1.9 m.?

803. A cubic foot of a certain gas has a density = 1; this density is increased successively to 1.1, 1.3, 1.5, 1.8 and 2. Find the corresponding volumes of the gas, expressed in cubic inches.

804. The density of a cub. ft. of a certain gas = 1, with the barometer at 28 in. What will be the respective densities of a cub. ft. of the same gas, when the barometer stands at 28.28, 28.56, 28.84, 29.12 and 29.4 inch? (Express answers in decimals.)

805. The volume of a certain gas = 1, with the barometer at 20 inch., and diminishes under different pressures, becoming successively 0.8, 0.7, 0.6 and 0.5. Find the corresponding tensions of the gas, expressed in mercurial columns.

806. Find the corresponding tensions of the gas in the preceding example, with the barometer at 400 mm. when the volume = 1.

807. A body of air fills the space of 1 cub. ft., barom. at 30 inch. Find the space it occupies with the bar. at 27 inch.

808. The volume of a body of air = 1 cub. m., barom. 600 mm. Find the volume with barometer at 700 mm.

809. A balloon, diam. 10 ft., was filled to its utmost capacity with air when the barometer stood 29 inch. What volume of air will pass out when the bar. sinks to 28 in.?

810. What is the difference between the weight of a cubic meter of air at 760 mm. and one at 700 mm.? (Take weight of a liter of air at 760 mm. = 1.3 grams.)

811. A receiver of 5 liters capacity was made to contain the following gases: 2 liters of hydrogen at a pressure of 3 atmospheres; 5 liters of carbonic acid at a pressure of 2 atmospheres; and 3 liters of oxygen at a pressure of 1 atmosphere. Required the pressure of the mixture, the temperature during the experiment being supposed to remain constant. (C. & M.)

812. The receiver of an air-pump contains 5 liters of air. Its upper portion communicates with a barometer, the mercury of which stands at 0 as long as the receiver contains air of ordinary atmospheric pressure. After a few strokes of

the piston the mercury rises to 650 mm. The pressure of the atmosphere during the experiment = 760 mm.; the temp. = 0°C. Find the weight of the air withdrawn from the receiver. (C. & M.)

AIR-PUMP.

(After the first stroke of the piston, the pressure, or tension, of air in receiver, $x = \frac{P\,V}{V+v}$; or by proportion, $x : P :: V : (V + v)$; where v = capacity of cylinder, V = capacity of receiver (and communicating tube), P = the original pressure of the air. And the pressure after n strokes $= P\left(\frac{V}{V+v}\right)^n$.)

815. Describe the principal parts of the common air-pump.

816. Why can no perfect vacuum be obtained by means of this air-pump?

817. Give position of valves during upward and downward strokes of the piston.

818. What causes each valve to close? Why should the valves weigh but little?

819. Why is the tension of the air in the receiver reduced after every stroke of the piston? Give formula for finding the amount of this reduction.

820. I place a receiver upon the plate of an air-pump, and then greatly rarify the air outside of the pump. How will this affect my subsequent exhaustion of the receiver by the pump?

(In the following examples disregard the capacity of the tube.)

821. The capacity of the receiver of an air pump = 240 cub. inch.; that of the cylinder = 48 cub. in. Find the tension of the air remaining in the receiver after the fifth stroke of the piston. (Solution on next page.)

(Capacity of the cylinder $= \frac{1}{2}$ capacity of receiver; hence, the pressure or tension of air in receiver after the first stroke $= 15 \cdot \frac{2}{3} = 12\frac{1}{2}$ pds.; and after the fifth stroke: $15 \cdot (\frac{2}{3})^5 = 6+$ pds. per square inch of surface.)

822. Find the tension of the air in the receiver of an air-pump after the first stroke of the piston, the cylinder having the same capacity as the receiver.

823. In the preceding example find the tension of air after the second stroke; after the tenth; after the nth.

824. Find the tension of the air in the receiver of an air pump after the first stroke of the piston, the capacity of the receiver being twice that of the cylinder.

825. As in preceding example, find the tension of air after the first stroke of the piston, the capacity of the receiver being three times that of the cylinder.

826. Find tension of air after the first stroke of the piston when capacity of receiver is ten times, and when n times, that of cylinder.

827. In example 821 find the weight of the air left in the receiver after the fifth stroke, if before exhaustion the weight = 40 grains (temperature disregarded)?

828. In example 821 find the height of mercury indicating the tension of air in the receiver after the fifth stroke.

829. Find the tension of the air in the receiver of an air-pump after the second stroke of the piston, the cap. of receiver and cylinder being respectively 5 lit. and 1 lit.

830. Required the weight of the air remaining after the fourth stroke in the preceding example.

831. The exhaustion of a pair of Magdeburg hemispheres, 10 cent. diam., was discontinued when the mercurial column connected with them stood 3 mm. high. Find the force required to pull them asunder (barometer 750 mm.; thickness of hemispheres neglected).

832. Find the force required to lift the piston of an air-pump, the mercurial column connected with the receiver standing 1 inch high; area of piston=4 sq. inch, and barometer 28 inch.

833. Find the force required to lift the piston of an air-pump, the mercurial column connected with the receiver standing 5 mm. high; area of piston 20 sq. cent., and barometer 750 mm.

CONDENSER.

In these examples the receiver is supposed to be below the condensing cylinder; the capacity of the tube is disregarded.

(After n strokes of the piston—in the direction toward the receiver—the pressure or tension of air in the receiver, x, $= P\frac{V+vn}{V}$; or, by proportion, $x : P :: V+nv : V$, where P is the original pressure of the air in the receiver, $V =$ the capacity of the receiver with the communicating tube, $v =$ capacity of the condenser or cylinder.)

835. Describe the principal parts of the condenser.

836. Explain the action of the condenser.

837. State the main difference between the construction of a condenser and the common air-pump.

838. What is the position of the valves during the downward and upward strokes of the piston?

839. What causes each valve to close?

840. Why does each downward stroke of the piston increase the tension of air in the receiver? Give formula for finding the amount of this increase?

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841. Find the tension of the air in the cylinder of a condenser whose capacity is the same as that of the receiver, after the first (downward) stroke of the piston; after the second; and after the third.

(Let v = capacity of cylinder; after the first stroke the receiver will contain the original volume of air *plus* another v, in all, 2 v, and the tension = 2 atmosph.; after the second stroke it will contain 3 v, and the tension then = 3 atmosph.; after the third stroke the tension = 4 atmospheres.)

842. In the preceding example what will be the tension respectively after the tenth, thirtieth, and *n*th stroke?

843. What will be the tension of air in the receiver after the first stroke of the piston, the capacity of the cylinder being ½ that of the receiver?

844. What will be the tension after the first stroke, if cap. of cylinder = ⅓ that of receiver? If ¼? $\frac{1}{10}$? $\frac{1}{n}$?

845. The capacity of the receiver of a condenser = 200 cubic inches, that of cylinder = 25 cubic inches. Find the pressure of air in receiver after the first stroke of the piston. Find the pressure after the fifth stroke, and after the tenth.

846. Supposing the air in the receiver of preceding example, before condensation, to weigh 33 grains, what will be its weight respectively after the first, fifth and tenth strokes?

847. In preceding example find height of mercury indicating the tension of the air in the receiver after the first, fifth and tenth strokes, barometer at 28 inch. before condensation.

848. The cap. of the receiver of a condenser = 4 liters; find the tension (per square centimeter) of air in receiver after the first, fourth and tenth strokes of the piston; capacity of cylinder = 1 liter.

849. What weight of air will be in the receiver of the preceding example after the tenth stroke?

850. Find height of mercury columns corresponding to tensions found in example 848, with the barometer at 750 mm.

851. The capacity of cylinder and receiver being as 1 to 1½, after how many downward strokes of the piston will the air in the receiver have four times its original tension?

852. Capacity of receiver $= a$; cap. of cylinder $= b$; find amount of compression after n downward strokes of the piston.

SYPHON.

855. What is a syphon?

856. On what conditions will the syphon flow?

857. Explain the action of the syphon.

858. Under what circumstances will the liquid in a syphon remain stationary? Under what circumstances will it flow back into the vessel?

859. Is it true, as is commonly believed, that the two limbs of a syphon must be of unequal length? Explain your answer.

860. Why is the height limited to which a liquid can be raised in a syphon? On what does that height depend?

861. The tube of a syphon has a cross-area of ¼ sq. inch, and its open end is 16 inches vertically below the surface of the liquid in the vessel. What is the effect of atmospheric pressure?

($\frac{1}{4} \cdot 16 = 12$ cubic in., and $12 \cdot 0.0361898 = 0.4342776$ pounds of water. Subtracting this from 15 pounds, we have 14.5657224 pounds, answer.)

862. Find the vel. of the stream in the preceding example (the vessel not being replenished).

863. Find the volume of water issuing from the syphon of the preceding example in an hour, the vessel being constantly replenished.

864. If a syphon be made to float on water, does that affect the velocity of the stream issuing from it?

865. The tube of a syphon has a cross-area of 1 sq. cent., and its open end is $\frac{1}{8}$ meter vertically below the surface of the water in the vessel. Required the effect of atmospheric pressure.

866. In the preceding ex. what is the vel. of the stream?

867. How many liters of water will issue in an hour from the syphon of ex. 865, the vessel being constantly replenished?

868. How far vertically below the surface of the water in the vessel must the open end of a syphon be whose sectional area = 2 square centimetres, so as to yield 24 liters of water per minute? (g = 10 m.)

869. A quantity of alcohol, sp. gr. 0.79, is to be transferred by means of a syphon where the barometer stands 28.5 inch. Find the maximum vertical height to which the alcohol may be raised in the immersed branch of the syphon.

870. Find the maximum vertical height to which sulphuric acid, sp. gr. 1.8, may be raised in the immersed branch of a syphon, with the barometer at 29 inch.

871. With the barometer at 756 mm. find the height of alcohol in example 869.

PUMPS AND AIR-CHAMBERS.

(Force necessary to lift the piston in a suction-pump = $(h+h')$ s, where h = height (above the piston) of a column of water whose base is area s of piston, and h' = height of column of water below the piston.)

875. Describe the action of a suction-pump.

876. State the principal parts of a suction-pump; also, the action of the valves.

877. State the conditions required to operate a suction-pump.

878. How would a suction-pump act in a vacuum?

879. State and explain the formula of the force necessary to lift the piston in a suction-pump.

880. Make a sketch of a common air-pump; also, by the side of it, a sketch of a suction-pump, and indicate two points of similarity.

881. The cross-area of the piston in a suction-pump = 6 square inches; the distance between the spout and the piston at the time being three feet; distance between the piston and the surface of the water in the cistern = 12 feet. What power must be applied to the piston rod to lift the piston?

882. In the preceding example, does it matter where the piston happens to be?

883. Suppose the piston of the pump in example 881 is to make 10 upward strokes per minute, each 4 feet high; what will be the work done in 1 minute?

884. In the preceding example, find the quantity of water obtained per hour.

885. The cross-area of the piston in a suction-pump = 22 square cent.; distance between spout and piston 1 meter; distance between piston and liquid surface in the cistern = 4 meters. Find the power required to lift the piston.

886. If the piston in the preceding example makes 15 strokes per minute, each 1.2 meters high, what is the work done in 1 minute?

887. How many liters of water will the pump in the preceding example yield in an hour?

888. The suction-pipe of a lifting-pump has a length of 3 m., the barrel a length of 2 m. from the pipe to the spout; cross-area of piston 0.1 m.; at every upward stroke the piston passes over 0.4 m.; how many such strokes are required to yield 50 liters of water?

889. Explain the essential points of difference between a suction-pump and a force-pump.

892. If the air in an air-chamber or a Hero's fountain be compressed into half its former space, what will be the height of a vertically rising jet supposed to move without resistance? (Barometer 29 inches.)

893. What would be the height of the jet with the barometer at 750 mm.?

894. How long would the jet in examples 892 and 893 remain at that height?

895. The air enclosed in a Hero's fountain occupies a space of 1 liter. I then blow 200 c. c. of air into it by means of a tube. What will be the height of the jet (bar. 756 mm.)?

BALLOONS.

(The ascensional power of a balloon, that is, the amount which a balloon will carry up, = the difference between weight of volume of air displaced and weight of balloon + weight of contained gas; or = W—(W′+w), where W is the weight of air displaced, W′ the weight of the gas and w the weight of the balloon. Take the ascensional power of hydrogen = 1.2 grams for every liter of hydrogen.)

900. A body occupies a space of 4 cubic feet; find its weight in *vacuo*, if its weight in air (s. g. $\frac{1}{770}$) = 687⅓.

901. A body occupies a space of 1½ cubic meters; find its weight in *vacuo*, if its weight in air = 3542 kils.

902. A body weighs 1000 pounds in *vacuo*, and occupies a space of 5 cubic feet; find its weight in air.

903. A body weighing 400 kilos in *vacuo* occupies a space of 0.385 cubic meters; find its weight in air.

904. A leaden bullet, diam. 0.012 m., suspended from one end of the beam of a balance is balanced by a glass ball 0.16 m. in diameter suspended from the other end of the balance; but if the whole be placed under a receiver from which the air is entirely removed, one of the balls will sink. Question: In *vacuo* which ball will sink, and what is then the difference in weight? (B.)

905. A balloon of 1000 cubic feet capacity is filled with a gas of which a cubic foot weighs $\frac{4}{5}$ ounces. The balloon itself weighs 15 pounds. Required its ascensional power (sp. gr. of air $\frac{1}{770}$).

(Weight of 1000 cubic feet of air $= \frac{1000 \cdot 62\frac{1}{2}}{770} = 81.15$ pds. Weight of balloon + gas = 15 + 50 = 65 pds.; 81.15 — 65 = 16.15 pds., answer.)

906. A balloon filled with hydrogen gas occupies a space of 200 cubic meters. The weight of the balloon, cordage, basket, etc., = 60 kilos. The weight of a liter of atmospheric air = 1.3 grams; the sp. gr. of hydrogen = 0.0688 (air = 1). Find the ascensional power of the balloon, that is, the weight which the balloon can lift at the instant of its rise.

907. A balloon whose capacity is 100 cub. meters is filled with gas, a liter of which weighs 0.8 grams. The balloon itself weighs 20 kilos. Required its ascensional power.

908. A spherical balloon of 40 m. diameter is filled with illuminating gas of sp. gr. 0.6. One square meter of the tissue weighs 200 grams; the basket, ropes, etc., weigh together 32.9 kilos. Required the ascensional power of the balloon.

909. A balloon made of tissue paper has a diameter of 5 feet; it is filled with air, which, having been heated, has expanded $\frac{1}{7}$ of its former bulk. The balloon itself weighs 3 ozs. Required the ascensional power of the balloon.

ÆRODYNAMICS.

(Vel. of efflux of gases into a vacuum $= \sqrt{2g\frac{h}{d}}$, where h = height of column of atmosphere indicated by height of column of mercury or water; d = density (either $\frac{1}{10\frac{1}{2}00}$ or $\frac{1}{7\frac{1}{10}}$) of atmospheric air, (mercury or water being 1).

Vel. of efflux of air into a space filled with air, or any other gas, of less tension $= \sqrt{2g\frac{h-h'}{d}}$ where h′ is the ideal height of column of air, or gas, of less tension.

913. Explain the formula for velocity of gases flowing into a vacuum.

914. Give the formula for the velocity of gases issuing into a space containing air or a gas of less pressure.

915. Prove that the lighter a gas, the greater its velocity of efflux, and state the precise law.

916. What is the velocity of air flowing into a vacuum when the barometer is at 28 inches?

$$\left(v = \sqrt{2g\frac{h}{\frac{1}{10\frac{1}{2}00}} \cdot \frac{28}{30}} = 8\sqrt{\frac{30}{\frac{1}{10\frac{1}{2}00}} \cdot \frac{28}{30}} = 8\sqrt{24500\text{ ft}} = \right.$$

1252 ft. +.)

917. Required the velocity of air flowing into a vacuum, barometer at 756 mm.

918. What is the velocity of air rushing into a vacuum if its tension corresponds to a mercurial column of 40 inch. (barometer 29 inch).

919. Find the velocity of air rushing into a vacuum if its tension is measured by a mercurial column 912 mm. high (barometer 760 mm).

920. What is the velocity of air issuing from a vessel in which it was compressed into ⅔ of its volume (bar. 760 mm.)?

921. What is the vel. of hydrogen rushing into a vacuum?

922. The illumating gas (sp. gr. 0.6) flowing from a gasometer has its pressure measured by a column of water 6.8 in. high. Required the velocity of the gas.

923. What volume of air flows in one minute from a vessel through an orifice whose area = 5 square centim., if the air is constantly subjected to the pressure of a column of water 1.5 m. high. (Coeff. of efflux 0.7.)

924. What volume of air flows in an hour through an orifice of 3 square inches if the air is pressed upon by a column of mercury 5 inches high (barometer 30 inches).

925. What volume of illuminating gas (sp. gr. 0.6) issues per hour from a burner whose sectional area = 0.01 sq. inch, if the pressure in the gasometer = 6 inches water?

PROPERTIES OF MATTER.

928. Define the term "Physics" or "Natural Philosophy."

929. What is a *phenomenon?* Illustrate your answer.

930. What is a physical law?

931. What is a physical theory? A physical hypothesis?

932. State the methods by which physical science has been studied, and explain each.

933. Mention an instance of a physical change as distinguished from a chemical change.

934. What is understood by the term "physical sciences?"

935. How old is the science of physics proper?

936. What is the purpose of physics?

937. I ask you to represent *graphically* the variations of the barometer during a day. Show by a sketch how you will do it.

938. Represent graphically any series of variations of a thermometer.

939. If all time-pieces on the globe were lost, how could we tell the time?

940. What connection has a second of time with the revolution of the earth round the sun?

941. What are the universal properties of matter?

942. Mention two properties of matter without which the existence of bodies cannot be conceived.

943. What are accessory properties of matter? Mention and illustrate five.

944. State the properties of matter exhibited in a rain drop.

945. What properties of matter does compressed air illustrate?

946. What are the three "states" of matter?

947. State two ways in which the volume of bodies can be changed.

948. What properties of matter are illustrated when in a pint of water I dissolve, first, sugar, until the solution is saturated; next, a small quantity of salt?

949. What do you understand by a molecule of common salt?

950. What is meant by an atom of chlorine gas? Of gold?

951. How would you prove the impenetrability of bodies?

952. Find the length of a kilogram of copper drawn into wire of 0.16 cent. diam. (sp. gr. of copper 8.88.) (A.)

953. A silver wire 6 mm. in diameter and 0.4 m. in length was drawn out into wire of 225 kilometers length; find its diameter.

954. A leaden bullet ½ inch in diameter is hammered into a sheet of ¼ sq. ft. surface. Find thickness of sheet.

955. A cylindrical silver wire 0.0015 m. in diameter weighs 3.2875 grams; it is to be covered with a layer of gold 0.002 m. in thickness. Required the weight of the gold (sp. gr. of silver 10.47; of gold 19.26). (A.)

Solution.. — If r is the radius of the silver wire, and R its radius when covered with gold, then $r = 0.075$ cm. and $R = 0.095$ cm. The volume of the silver wire will be $\pi r^2 l$, and its weight $\pi r^2 l$ (10.47), from which $l = 17.768$ cm.

The volume of the layer of gold is $\pi (R^2 - r^2) 17.768$, and its weight: $\pi (0.095^2 - 0.075^2) \cdot 17.768 \cdot 19.26 = 3.657$ nearly.

956. Distinguish between adhesion and cohesion.

957. Give instances of capillary attraction, capillary repulsion, and capillary depression.

958. State the law concerning the heights to which a liquid may rise in tubes of different bores.

959. Explain endosmose and exosmose.

960. State six properties of matter, and mention their application, or use, in daily life.

961. Define elasticity.

962. Define malleability, ductility and brittleness.

963. Define hardness. How would you ascertain the relative hardness of quartz and limestone?

964. What is meant by the limit of elasticity?

965. Compare gases, solids and liquids with each other as regards their elasticity.

966. Define tenacity or absolute resistance.

967. Compare the characteristic properties of a copper wire, a steel spring and a glass rod with each other.

968. How can you render a steel spring inelastic, and a glass rod elastic?

969. What is meant by elasticity of torsion? of flexure? of compression? of elongation?

970. Define the term "perfect elasticity."

971. What is meant by the modulus of elasticity?

WAVES.

1001. Define *length*, *amplitude* and *velocity* of a wave.

1002. Sketch a wave 2 inches long, amplitude ½ inch; also a wave 4 inches long, amplitude 1 inch.

1003. If 300 waves, each of 200 ft. velocity (per second), pass a certain point in a second, find the length of the waves.

(Let x = the length; then 200 = 300 x; hence x = ⅔ ft. or 8 inches, answer.)

1004. Find the length of a wave 1000 of which pass a certain point in a second, with a velocity of 500 feet each.

1005. A wave is 6 inches long, its velocity = 150 feet per second. Required the number of waves passing a certain point in one second.

1006. What is the velocity of waves each 1½ ft. long, 200 of which pass a certain point in a second?

1007. The length of a wave is 8 inches, and its velocity= 100 feet per second. Find the number of waves passing a certain point in a second.

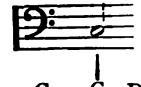
1008. How many waves each 2 inches long, with amplitude of ½ inch, are contained in a space of 5 feet?

1009. A pebble dropped into water produced circular concentric waves, the waves being 4 inches from crest to crest, the outside circle having a diameter of 10 feet. How many waves were propagated?

1010. Give a clear description of the manner in which an ordinary water-wave is propagated.

1011. Describe what occurs when two series of water-waves cross each other.

SOUND.



	C_{-2}	C_{-1}	C	D	E	F	G	A	B	C_1
Rel. numb. of vibr. -			1	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	2
New scale of double vibr.	33	66	132	148½	165	176	198	220	247½	264
Length of wave (in meters)			2.585							

Length of sound-wave, air	= 1.	Vel. of sound, air	= 333 m.
" " carb. ac.	= 0.8	" " carb. ac.	= 266 m.
" " ill. gas	= 1.6	" " ill. gas.	= 533 m.
" " hydrog.	= 3.56	" " hydrog.	= 1186 m.

1012. Define Sound.

1013. Describe a wave of sound. What is meant by the length of a wave of sound.

1014. Describe the manner in which sound is propagated through air, water or wood.

1015. Describe an experiment to prove that sound cannot pass through a vacuum. (S. K.)

1016. How are echoes produced? State all you know regarding the law which regulates the production of echoes.

1017. State what is meant by the *velocity* of sound, the *intensity* of sound, and by the pitch of a musical sound.

1018. How has the velocity of sound been determined?

1019. You fire a shot before a cliff, and hear the echo five seconds afterward. What is the cliff's distance from the centre of explosion? (T.)

1020. One day when the temperature of the air was 32°F., I saw the flash of a gun, and heard the report half a minute afterwards. What was the distance of the gun, and why do I mention a particular temperature? (T.)

1021. How is the vel. of sound affected by temperature?

1022. How is the velocity of sound affected hy the rarity or density of the atmosphere?

1023. Supposing the velocity of sound to augment 2 feet per second for every degree C. of temperature above the freezing point, what will be the temperature of air in which the velocity of sound is 1500 feet a second?

1024. The velocity of sound in water is much greater than its velocity in air. Why is this the case?

1025. A steam whistle is to be heard with equal loudness by three persons occupying the corners of a triangle. Where must it be placed to be heard equally well by each person?

1026. A cannon was fired on board a vessel in distress. An observer on shore counted 46 beats of his pulse from the time he saw the flash until he heard the report, His pulse was beating 69 times a minute; the temperature of the air was 16°C. Find distance of the vessel from the observer.

1027. The vel. of sound in air at a temperature of 0°C is 1090 feet a second; the length of each sound wave of a series in such air is four feet. Determine the number of vibrations executed by the body which produces the sound? (T.)

1028. The wave-length of a sound = 6 ft.; find the number of vibrations of the sound.

1029. The numbers of vibration of two sounds are as 5 to $8\frac{1}{2}$; find the ratios of their wave-lengths.

1030. How many vibrations per second are necessary for the formation of sound-waves 3 feet in length?

1031. Give the law ot intensity of sound, and illustrate it.

VIBRATIONS.

1037. The circumference of a wheel has 100 teeth which strike against an elastic strip. Find the number of vibrations of the sound produced per second, when the wheel rotates 3 times per second.

1038. Find the number of vibrations per second of G_3.

1039. Give number of vibrations per second for the tones of the scale from C_2 to C_3.

1040. Find the number of vibrations of E_2; of A_4; of A_5.

1041. The tones within the compass of the human ear range between 16 vibrations and 38000 vibrations. How many octaves is this?

1042. Find the number of vibrations of a tuning fork sounding D_3. Also the wave-length of D_3.

1043. What is the cause of consonance and dissonance in music?

1044. Explain *beats* in music?

1045. How are musical sounds produced? On what do *pitch* and *intensity* of musical sounds depend?

1046. How may the "singing" of telegraph wires be prevented?

1047. What is the part played by the wooden portion of a violin in the production of sound?

1048. Two musical sounds, the one produced by 400, the other by 410 vibrations per second, pass through the same air; state and explain what is heard? (T.)

1049. How is the rate of vibration of a string affected by its length, density, thickness and tension?

1050. How are nodes produced on a vibrating string?

1051. A musical string vibrates 400 times in a second. State what occurs when you shorten or lengthen the string without altering its tension; and also what occurs, when you increase or lessen its tension without altering its length. (T.)

1052. A string of 0.56 m. length sounds C_1. What sound is indicated by a string 1.335 m. long, the other conditions remaining the same?

1053. Give ratio of numbers of vibrations of two strings of like material, thickness and tension, whose length is $3\frac{1}{3}$ m. and $2\frac{1}{2}$ m. respectively.

1054. A string sounding A_4 is 50 cent. long. How long must one be to sound C, the remaining conditions being the same?

1055. A string is stretched by a weight of 36 pounds, and sounds F_1. What tone is given by a string stretched by 49 pounds, the other conditions remaining the same?

1056. Of two strings one is made of steel, the other of brass; their length, tension and radius being the same. What is the ratio of their numbers of vibration?

1057. A string whose radius $=$ 2.5 mm. makes 400 vibr. a second. How many vibrations are made by a string of 3.1 mm. radius, other conditions remaining the same.

1058. If you sing into an open piano, the strings will give out the same note if they are in unison. A piano also responds to the sound of a clarionet. A string of a violin can be set to vibrate in the presence of a vibrating tuning fork. What is the law concerning all this? (T.)

1059. Describe an open organ pipe, and explain the production of musical notes by such a pipe.

1060. Wherein does the transmission of sound through a smooth tube differ from its transmission through the open air?

1061. Describe the manner in which the air vibrates within an organ pipe when it sounds its fundamental note, its first harmonic and its second harmonic. (T.)

1062. Air and hydrogen gas are urged in succession through the same organ pipe. Describe the effects and explain them.

1063. A jar containing air and another containing hydrogen resound to the same tuning fork. Are the jars alike? If not, state and explain the difference between them. (T.)

1064. Two open organ pipes are in perfect unison being of the same length. I shorten one of them slightly. What will be the effect upon the ear when both of them are now sounded together? (T.)

1065. What is the length of an open organ pipe which produces sound-waves four feet long? What is the length of a stopped pipe producing waves of this length?

1066. What is the fundamental tone of an open organ pipe 5.17 meters long?

1067. What is the fundamental tone of the preceding pipe when covered?

1068. A tuning fork vibrates 512 times a second. What is the length of the sonorous wave which it would produce in an atmosphere of hydrogen, supposing the velocity of sound in hydrogen to be 4200 feet a second. (T.)

1069. Describe the manner in which a bell divides itself when it sounds its fundamental note. What other notes and modes of division are possible to the bell? (T.)

1070. What is the cause of variations of pitch produced by the fingering of a common flute? In other words, explain the action of the flute as a musical instrument. (T.)

1071. How are the musical sounds of an accordeon or mouth harmonica produced? State the similarity between the production of these sounds and that of the human voice.

1072. How do you suppose the human voice to be produced?

1073. What occurs in the case of your voice when you sing high notes and low notes? I mean, what is the condition of the vocal organ when the two kinds of notes are sounded? (T.)

HEAT.

SOURCES—MECHANICAL EQUIVALENT.

(A heat-unit = 772 ftpds. for 1°F; or 425 meterkilograms for 1°C.)

1081. Give the sources of heat and state which is the most important.

1082. What is the probable cause of the heat of the sun?

1083. How is the heat of a fire produced? Of coke? Of the human body?

1084. Why do ungreased wagon wheels become easily heated? How do you account for the sparks emitted from dry, rotating grindstones when steel utensils are being sharpened?

1085. State what you know regarding the different kinds of rays emitted by the sun.

1086. Describe some one means of determining the mechanical equivalent of heat?

1087. What is a heat-unit?

1088. Give a clear statement of the *mechanical* theory of heat, and explain how it differs from the *material* theory of heat?

1089. Explain what is meant by the conservation of energy.

1090. A weight of a ton is lifted to a height of 386 feet; into what amount of heat may this motion be converted?

1091. What is the mechanical equivalent of the heat required to convert one pound of ice into water at 0°C? One pound of water at 100°C into steam at 100°C?

1092. How many meter-kilograms of work are equivalent to the heat required to raise the temperature of 5 kilos of water 2°C?

1093. How many units of work are involved in raising the temperature of 3 pounds of water 40°F?

1094. How many units of work are involved in raising the temperature of 3 kilos of water 40°C?

1095. From what height must a block of ice at 0°C fall, that the heat generated by its collision with the earth shall be just competent to melt it? (D.)

1096. From what height must a block of ice at 0°fall that the heat generated may be sufficient to convert it into steam?

1097. A twelve-pound cannon ball with a velocity of 1605.8 feet a second strikes against a wall. Supposing all the heat generated by the collision to be communicated to 12 pounds of water at 160° F; to how many degrees would the temperature of the water be raised? ($g = 32.116$ ft.)

1098. How much work can be done by 1 pound of steam?

1099. A cannon ball, weighing 100 kil. and having 600 m. vel., strikes a cast iron target without penetrating it, or being reflected from it. What is the quantity of heat generated?

1100. What is the amount of work in 1 kil. of coal, the calorific power of which is 7500?

1101. Assuming the weight of the earth as 5 quintillions of tons, its orbital velocity at 1100 miles per minute, how many degrees would its temperature be raised if it were suddenly to come to rest and all its motion converted into heat?

CONDUCTION AND RADIATION.

(See table in Appendix.)

1105. You are provided with bars of copper, silver, gold and platinum, and are required to devise a means of determining their conductivities for heat. How will you proceed? (T.)

1106. You place one hand in mercury, the other in water. Both liquids having the same temperature, the hand in the mercury feels colder than the hand in the water. Why? (T.)

1107. Explain and illustrate the conduction of heat.

1108. How does conduction differ from convection?

1109. How does conduction differ from radiation?

1110. Are clothes really warm? If not, why are they sometimes called warm? What is the real meaning and action of cool dresses and warm dresses?

1111. Describe an experiment proving that water is a bad conductor.

1112. How may a large mass of water, such as that in a steam boiler, be readily heated?

1113. Give four metals in the order of their conductivity.

1114. Are gases good or bad conductors of heat?

1115. Give a clear statement of what you understand by the radiation of heat, and state the laws of the same.

1116. State what you know regarding the radiation of heat from the earth, and the effects produced by this radiation. (T.)

1117. How is the earth heated by the sun? How is our atmosphere heated?

ABSORPTION AND REFLECTION.

1120. State and illustrate what is meant by Athermancy and Diathermancy.

1121. Benjamin Franklin once exposed to sunlight on snow bits of cloth of different colors, and found that the darker the cloth the deeper it sunk in the snow. Give the explanation of this experiment.

Is it a fact that dark bodies are always more highly heated by the sun than light ones? If not, state and explain an exception. (T.)

1122. What is the effect of a transparent glass screen on the heat of a common fire?

1123. The air of a glass house into which the solar rays enter, may be warmed by those rays to a much greater degree than the air outside the house. What do you suppose to be the cause of this? (T.)

1124. A black hat is more heated by the solar rays than a white one. What is the reason? Dark iodine is, however, less heated by the same rays than white sugar. What is the reason? (T.)

1125. Explain the influence of the earth's atmosphere upon the temperature of the earth? (T.)

1126. Do you consider it possible by means of an atmosphere to raise the temperature of a planet more distant than the earth from the sun to the earth's temperature? If so, explain how it might be done. (T.)

1127. You are provided with plates of copper, silver, gold and platinum, and are required to devise a means of determining their radiative powers; how will you proceed? (T.)

1128. A thermometer placed in an open black box and exposed to the sun, rises to 80° F. A glass cover is placed on the box, and the temperature rises to 120°. Explain this, and apply your explanation to the possible influence of a planet's atmosphere in augmenting its temperature. (T.)

1129. A plate of rock salt if placed in front of a hot fire will not be heated, while a plate of glass will be heated. A hot plate of rock salt held at a short distance from the face hardly warms the face, while a hot plate of glass does warm it. Explain these effects. (T.)

1130. State what you know regarding the absorption of radiant heat by solids, liquids and gases. Explain in accordance with the mechanical theory of heat, what is meant by radiation and absorption. (T.)

1131. Show that a good radiator is also a good absorbent, and that bad radiators are bad absorbents.

1132. A thin plate of rock salt is heated to 100°. Its heat is allowed to pass through a thin plate of *cold* rock salt, and then to fall on a thermometer. The thermometer will show that the cold plate has stopped nearly three-fourths of the heat that it received from the hot plate. Explain.

TEMPERATURE.

(See Appendix.)

1134. Define the temperature of a body?

1135. Explain what is meant by the statement: "Two bodies are of the same temperature."

1136. Explain the construction of the common mercurial thermometer. How are the Fahrenheit, Reaumur and Centigrade thermometers graduated?

1137. How many degrees C = 54° F.? How many degrees F = 40° C; and how many degrees R = 100 F?

1138. Zinc boils at 1204° F, mercury at 608° F. Change these readings to degrees C.

1139. Change the following readings into degrees C: Polished steel is of a deep blue color at 580° F; it is of a pale straw color at 460° F.

1140. Express in the Centigrade scale the following temperatures of Fahrenheit: 10°, 0°, 212°, and — 10°.

1141. What is the advantage of an alcohol thermometer over a mercurial thermometer?

1142. Describe Breguet's metallic thermometer, and state its advantages.

1143. A certain definite amount of heat is communicated to a solid body without changing its state of aggregation. How is that heat disposed of within the body?

1144. Define absolute temperature and absolute zero.

EXPANSION.

(See Table in Appendix.)

1146. How are the volumes of bodies affected by heat? State an exception to the general rule.

1147. What do you know concerning the expansion of liquids?

1148. In warming a house by steam why is the boiler placed in the lowest part of the building? Why not at the top of the house?

1149. State clearly how you suppose winds to be produced?

1150. The rails from London to Manchester are 188 miles long. Suppose these rails to form one continuous piece at a temperature of 0° C, what will be their length at 20° C? (T.)

1151. What causes the bursting of water pipes in frosty weather, and how may it be prevented?

1152. Explain what is meant by the maximum density of water? State at what temperature it occurs, and mention at least two effects of it in nature.

1153. Mention two substances that expand on solidfication.

1154. What is the sun's action in the generation of winds?

1155. What advantage, if any, has an air thermometer over a mercurial one?

1156. Why cannot gold, silver and copper coins be cast in a mould, but must be stamped?

1157. Describe and explain the *gridiron* pendulum?

1158. Explain the *compensation balance* for chronometers.

1159. What is the coefficient of expansion of atmospheric air? Why is it that the coefficient of gases exhibits a much closer agreement than those of liquids and solids?

1160. Certain gases deviate from the normal standard in their expansion by heat. State what you know regarding the cause of this deviation, and the circumstances under which it is observed to occur. (T.)

1161. Why is it possible to fuse platinum wire into glass without fracture on cooling?

1162. If 200 cubic centimeters of a liquid at 0°C become 210 cubic centimeters at 50°, what is the average coefficient of expansion of the liquid?

(200 cub. c. expand 10 cub. cent. for 50°C, hence 200 cub. c. expand 0.2 cub. c. for 1°C; and 1 vol. expands 0.001 for 1°C; that is, the coeff. of expansion of the liquid=0.001.)

1163. If 200 cubic inches of alcohol at 0° become 250 cub. inches at 45°, what is its average coefficient of expansion?

1164. Suppose that a person bought a liter of spirits of wine at a temperature of — 10°C. What space would this occupy at + 32° C? (The coefficient of expansion is 0.001.)

1165. What is the average specific gravity of water at 80°C, water at 4°C being taken as the standard? The coefficient of expansion is 0.00018.

(In rising from 4° to 80° water will expand 76 times 0.00018 of its volume. Hence its sp. gr.$= \frac{1}{1 + (76.0.00018)} = \frac{1}{1.01368} = 0.9865$.)

1166. The specific gravity of a piece of lead at 0° was 11.335. Find its specific gravity at 100°C.

1167. The specific gravity of mercury at 0° is 13.6, what is it at 30°C?

1168. If 273 cub. cent. of air at 0° are heated 1°C, what will be their volume?

(Since the coeff. of expansion for gases $= \frac{1}{273}$ of their bulk at 0°, we have $273+(\frac{1}{273}$ of $273) = 274$ c. c.; or, by proportion, $273° : 273°+1° :: 273$ c. c. : x, whence $x = 274$ c. c.

1169. If 100 c. c. of air at 0° are heated 10°C, what will be their volume?

1170. What volume will 546 liters of hydrogen at 0° C occupy when heated to 21°C?

1171. If 588 liters of hydrogen at 21°C are reduced in temperature to 0°C, what space will they occupy?

($588 = x+(\frac{21}{273})$ x, whence $x = 546$ lit.)

1172. What space will 20 cubic feet of air at —100°C occupy when heated to 100°C?

1173. What space will 500 c. c. of air at 15°C occupy when cooled to 0°C?

1174. To what temperature must 273 volumes of a gas at 0°C be raised to expand to 295 volumes?

1175. What space will 1000 c. c. of hydrogen at 0°C take up when raised in temperature to 20°C, and what will be the weight of 1000 c. c. of hydrogen at 20°C?

1176. If a liter of air at 0°C weighs 1.3 grams, what will a liter of air at 40°C weigh?

1177. If the liter of air at 0°C in the preceding ex. was measured at a barometric pressure of 750 mm., what volume did it occupy at 40°C with a mercurial pressure of 740 mm.?

1178. Find the volume of 100 cubic meters of air at 0°C and a mercurial pressure of 760 mm., if the temperature be raised to 100°C and the pressure lowered to 740 mm.?

CHANGE OF STATE.

1180. Distinguish between solids and liquids; between liquids and gases.

1181. When does a liquid boil?

1182. What is meant by the *boiling point* of a liquid? What is the boiling point of water, and how can water be heated above its ordinary boiling point?

1183. How is the boiling point affected when we ascend a mountain? And why?

1184. Give two illustrations of question 1183.

1185. What is the chemical and physical constitution of aq. vapor, and how is it distributed in the atmosphere? (T.)

1186. How are clouds and rain formed?

1187. What is the meaning of the term *saturated*, as applied to air charged with vapor?

1188. Explain the formation of dew and hoar frost.

1189. Describe the influence of clouds and winds upon the formation of dew.

1190. If two bodies, one of which is a good radiator, the other a bad one, be put out of doors on a clear night, on which will most dew be deposited, and why?

1191. Explain regelation.

1192. Ice may be formed on a clear night in India when the temperature of the air is 15 or 16° F above the freezing point. How is this possible? (T.)

1193. What is distillation? On what does it depend?

1194. Distinguish between condensation and distillation.

1195. Explain and illustrate sublimation.

1196. What is the reason why in a Turkish bath, having a temperature of nearly 200°F, the human body remains at a temperature of 100°F? (T.)

1197. I place water, alcohol and ether, all of the same temperature, on my hand in succession. I experience a certain cold from the water, a greater cold from the alcohol, and a still greater cold from the ether. State what you know regarding the cause of these differences. (T.)

1198. Carbonic acid gas may, by powerful pressure, be reduced to the liquid condition. When the pressure is removed the liquid returns to the state of gas, but in doing so it produces solid carbonic acid, which has the appearance of snow. Explain this effect. (T.)

LATENT HEAT.

(Take the latent heat of water = 80°C.; the latent heat of steam at 100°=536°C. In these ex. specific heat is neglected.)

1201. What is meant by latent heat?

1202. Ten pounds of water are to be raised ten degrees in temperature. How many heat-units are required?

1203. The temperature of n kilos. of water is to be raised t°C. Find the number of heat-units required.

1204. Twenty kilos. of water at 0°C are converted into steam of ordinary atmosphericpressure. How many heat-units are required?

1205. One kilo. of ice at 0°C is to be converted into steam at 100°. How many heat-units are required?

1206. Two kilos. of boiling water are condensed into water at 30°C. How many heat-units are given out?

1207. What essential difference is there between the temperature of a body and the quantity of heat it contains?

1208. Ice at a temperature of 20°F, with a thermometer imbedded in it, is placed in a saucepan, and the saucepan is placed on a fire. The ice melts, the water is warmed, and finally boils. You observe the thermometer from first to last, what are its indications? (T.)

1209. What is the latent heat of water? Of steam?

1210. Distinguish between sensible and latent heat.

1211. Under what circumstances does heat become latent?

1212. Explain latent heat in terms of the dynamical theory of heat. (T.)

1213. How may the quantity of heat in a body be measured?

1214. Mention two uses made of latent heat.

1215. A pound of water at 0°C is placed together with a pound of water at 80°C. What will be the temperature of the two pounds of water?

1216. A pound of ice at 0°C and a pound of water at 80°C are mixed together. Find the temperature of the mixture, and explain your answer.

1217. A kilo. of steam at 100° is mixed with 12 pounds of water at 0°C. Find the resultant temperature.

(In latent heat, the number of heat-units received = the number of heat-units given out. Let x = the resulting temp. Then the loss of the steam is $537° + 1(100° - x°)$; and the gain of the water = $12x$. And $537 + (100 - x) = 12x$, whence $x = 49°$, answer.)

1218. A pound of steam is conducted into 4 pounds of crushed ice at 0°. Find temperature of mixture.

1219. Find the number of heat units required to convert 18 kilos. of ice at 0°C into steam at 100°C.

1220. Find the temperature of the water which is obtained when 4 pounds of boiling water are poured on 3 pounds of ice at 0° C.

(Let x = temperature. It is clear that the heat *lost* by the boiling water = the heat *gained* by the ice. Now the loss of the water = 4 (100—x); and the gain of the ice = 3 (80+x). Since 4 (100 — x) = 3 (80+x), we have x = $22\frac{6}{7}$°C, temp. of the mixture.)

1221. How many pounds of snow at 0°C must be mixed with 6 pounds of water at 100°C in order to obtain water of 10°C?

1222. How much ice will be converted into water at 5°C by 10 pounds of water at 90°C?

1223. How many pounds of ice at 0° will be melted and raised in temperature to 10°C by 90 pounds of water at 19°C, falling in temperature to 9°C?

1224. Two masses, m and m', of the same liquid, having the temperatures t_1 and t_2 respectively, are mixed together. The temperature of the mixture = t°. Find the equation expressing all this.

1225. Ten pounds of steam at 100° are passed into 1200 pounds of water at 4°C, and 20 pounds of floating ice at 0°. What will be the temperature of the mixture?

1226. Find the smallest weight of water at 32°F sufficient to condense a pound of steam at the ordinary atmospheric pressure into boiling water.

1227. How much water at 8°C must be added to 80 kils. of water at 50°C to produce a temperature of 20°C?

1228. An ounce of steam at 212°F is added to a pound of water at 50°F. Find the temperature of the mixture.

1229. Describe an apparatus for the artificial production of ice.

SPECIFIC HEAT.

(See Table in Appendix.)

1232. Define specific heat.

1233. I heat a ball of lead and one of iron to the temperature of boiling water. I then place both balls on wax or snow. Will they sink to the same depth? State what you know regarding the subject touched upon in this question. (T.)

1234. How much ice may be melted by means of 54 pds. of iron having 500°C of temperature? (Take specific heat of iron $= \frac{1}{9}$.)

($54 \cdot 500 \cdot \frac{1}{9} = 80$ x, whence x $= 37.5$ pounds.)

1235. A pound of iron at a temperature of 160°C is immersed in a pound of water at a temperature of 50°C. How many degrees will the temperature of the water be exalted? (Specific heat of iron $= 0.1$.)

1236. A pound of cold iron is placed in a pound of water of a higher temperature. The water loses 5° of temperature. How much has the iron gained in temperature?

1237. A pound of lead at 50°C is immersed in a pound of water of 0°C. What will be the resulting temperature of both, the specific heat of lead being 0.031?

1238. You are furnished with an ounce of each of the following metals, and are required to determine their specific heats: Gold, silver, copper, iron, lead, bismuth. How will you proceed, and what results would be obtained? (T.)

1239. One pound of mercury at 96°C is thrown into one pound of water at 5°C. Find the temperature of the mixture.

1240. One kilogram of iron at its welding point, 833°C, is thrown into 50 kils. of water at 0°. Find the temperature of the mixture.

1241. 5½ pounds of cast iron at 100° melt 0.81 pounds of ice. Find the specific heat of the iron.

1242. How much iron will be raised from 18° to 30° with the heat given out by 3 kilos of water sinking from 60 to 50°C?

1243. A ton of air at 600C° (at the ordinary pressure) is passed through oil originally at 7°C; the air is allowed to sink to 28°C. How much oil will it raise to the temperature of 28°C?

1244. Twenty grams of carbonic acid gas at 680°C, and at ordinary pressure, are passed through a kil. of water at 0°C, and escape at the temperature of 30°. Find the temperature of the water (the solubility of the gas in water being neglected).

1245. Eight pounds of mercury at 50°C and 12 pounds of mercury at 0° are put together. Find resulting temperature.

1246. Explain the influence which the specific heat of water has upon climate.

1247. Why is there a difference between the specific heat of air at constant pressure and at constant volume?

1248. The specific heat of air being ¼ that of water, and its specific gravity $\frac{1}{770}$, water being unit, suppose a cubic mile of water to give up one degree of its heat; by what quantity will 1000 cubic miles of the atmosphere be heated?

1249. In an experiment to determine the specific heat of mercury, 80 grams of it were heated up to 98°C, and the mass was then thrown into a glass flask containing 112 grams of water at 10°C. After being well agitated, the water was found to have risen in temperature to 12°C. Deduce the specific heat of mercury. (D.)

1250. In order to find the heat of a smelting furnace a platinum ball weighing 100 grams was introduced into it, and after remaining there some time was withdrawn and plunged

into a mass of water whose weight was one kilogram and temperature 9°C; and, when the temperatures had become equalized, the resultant temperature was found to be 13°C. What was the temperature of the furnace? (D.)

1251. An iron ball weighing 83 grams, and heated up to 340°C, was plunged into 50 grams of water at 10°C; when the ball had thoroughly cooled, what was the temperature of the water? (D.)

1252. A platinum ball weighing 200 grams was heated in a furnace, and then plunged into 1000 grams of water. In consequence of this the temperature of the water rose from 13° to 20°C. What was the temperature of the furnace? (D.)

1253. A cubic foot of water at 70°F is placed in contact with 100 cubic feet of air at 50°; the water sinks to 69°; supposing all the heat that the water has lost to be communicated to the air, what would be the exaltation of the temperature of the air? (Take the weight of a cub. foot of water at 70° = 62 pounds.)

1254. Find the number of heat-units required to convert eighteen pounds of ice at — 10°C into steam at 100°C

MISCELLANEOUS.

1260. Explain why

a—water boils sooner in iron vessels than in earthenware;
b—water boils sooner in vessels with dull outside surface than in vessels with bright surface;
c—beds, woolen garments and furs protect against cold;
d—ice may be preserved in a blanket longer than in a metallic kettle;
e—metallic objects should in severe cold not be touched with moist hands;
f—a burning taper is readily extinguished on a cold met. surface;
g—double sets of windows protect against cold better than panes of double thickness;
h—more time is required to heat water when the fire is by the side of it than when the fire is below the water.

1261. Explain why

a—a thermometer whose bulb is blackened with soot, when exposed to the sun's rays, rises more rapidly than one not blackened;
b—snow, if covered with a film of sand or soot, melts more rapidly in the light of the sun;
c—fruit growing against a wall ripens a little sooner;
d—no dew is formed in cloudy weather;
e—when the hand is held against a heated object, the side of the hand turned toward the object feels warmer than the other side;
f—steam radiators should have a rough, dull surface, while boiler-steam tubes should be brightly polished.

1262. Explain why

a—tires are heated before being placed on wheels;
b—oil barrels if filled in winter should not be made quite full;
c—glass and some other bodies crack if not heated or cooled uniformly;
d—glass vessels, such as retorts, that are to resist intense heat should be made thin;
e—before filling a flask with hot liquid it should first be warmed;
f—the rails of a railway track, if laid in cold weather, should not be laid so as to touch one another;
g—in accurate measurements the temperature of the measuring instrument must be considered;
h—a sudden change of temperature changes the tone of a piano. State how the tone is altered when the change is from cold to warm.

1263. Explain why

a—moist clay or wood contracts on being heated;
b—the cover of a book lying in the sun warps;
c—water pails are preserved moist in summer, but left dry in winter;
d—pitchers crack if containing water in the state of freezing;
e—drops of water form on the inner side of the cover of a vessel filled with warm water;
f—a cold tumbler on being held over steam becomes coated with moisture;
g—the outside of a vessel filled with cold water and brought into a warm room becomes coated with moisture.

1264. Explain why

a—the boiling point of water is lower as the atmospheric pressure decreases;
b—on high mountains meat to be done well must be boiled in closed vessels;
c—the alcohol in a thermometer may indicate 100°C, or beyond, although alcohol boils at 78°C;
d—why clothes dry more rapidly on windy days than in moist weather;
e—the sensation of cold after moistening one's forehead with ether;
f—to detect the existence of wind, mariners sometimes moisten a finger and hold it up in the air;
g—in summer rooms are kept cool by sprinkling;
h—we cool ourselves by fanning;
i—moist garments are injurious to health;
j—water or ether placed on the bulb of a thermometer causes the liquid within to sink;
k—fluids in vessels may be kept cool in summer by being tightly covered with wet flannel;
l—ice forms readily in a vacuum;
m—when frozen potatoes are placed in cold water, the water will freeze around the potatoes;
n—salt is placed on rails covered with snow or ice.

1265. What are the effects of heat? Illustrate each by a familiar instance.

STEAM.

1270. What is meant by a *saturated* volume of air?

1271. What is *high-pressure* steam?

1272. What is the numerical expression for the work done when steam, at an effective pressure of 20 pounds to the square inch, forces a piston 20 inches in diameter through a space of two feet against a resistance?

1273. The boiler of a steam engine should be several times as strong as the greatest pressure of steam to which it is subjected; the heat of the fire should not be wasted unnecessarily, and a sufficient supply of air should be provided for the burning of the fuel. How would you design and fit up a boiler so as to fulfil these requirements?

1274. Describe Newcomen's atmospheric pumping engine, and point out its defects.

1275. How does the steam act in (1) a single-acting condensing engine; (2) a double-acting condensing engine; (3) a high-pressure engine?

1276. Describe with a sketch some form of slide-valve as connected with the steam cylinder of an engine, and explain its action.

1277. Describe the method of working a slide-valve by an eccentric.

1278. Explain the action of the governor and throttle-valve in regulating the speed of an engine.

1279. What relationship in principle exists between the pendulum of a clock and the governor of a steam engine?

(S. K).

1280. Define the *lap* of a slide valve, and state the object of putting lap upon a slide.

1281. Describe the construction of a piston, and explain how the piston and piston rod are kept steam-tight.

1282. Explain the purpose of the fly wheel.

1283. Describe with a sketch the locomotive boiler. Why is it essential to discharge the waste steam up the chimney?

1284. Describe the safety-valve of a locomotive boiler.

1285. Sketch and explain the arrangement of the feed pump, and valves connected with it, as fitted to a locomotive boiler.

1286. What are the main difficulties which were overcome by Stevenson's invention of the locomotive engine and boiler?

1287. Point out the advantages resulting from the expansive working of steam.

1288. Describe generally the improvements introduced by Watt into the steam engine.

1289. Explain why Watt's single-acting pumping engine is so much more economical in steam than Newcomen's.

1290. Describe the arrangement of the condenser and air-pump of a condensing engine and the valves connected therewith.

1291. The length of the stroke of an engine is 8 feet; the pressure of the steam on entering the cylinder is 30 pounds to the inch; at what point should the steam be cut off so that the pressure at the end of the stroke may be 5 pds. per inch?

1292. The stroke of the piston of an engine is 24 inches, and the diameter of the driving wheel is 8 feet. What is the number of strokes per minute of the piston when the engine is running at 40 miles an hour?

1293. Describe the indicator.

1294. What is meant by the terms *cushioning* and *clearance*?

1295. Describe the screw propeller. How is the thrust of the propeller received upon the vessel?

LIGHT.

1301. What is meant by the corpuscular theory of light, and how do you explain the undulatory theory?

1302. Which of these theories seems to you the true one? State at least two reasons for your assertion.

1303. Explain the necessity of assuming the existence of an *ether*, and state what its vibrations give rise to.

1304. What are the sources of light, and which is the most important one?

1305. Give some proof that light itself is invisible. (T.)

1306. Define a ray and a pencil of light.

1307. What is meant by the scattering of light, and what by its regular reflection? (T.)

1308. Distinguish between a luminous body and an illuminated one.

1309. Distinguish between transparent and opaque bodies.

1310. When are shadows formed? When penumbras?

1311. An opaque square plate, each side 2½ inches long, is held in front of the eye and 8 inches from the eye; find the area which at a distance of 400 feet is concealed by this plate.

1312. A disk of 0.5 m. diameter is illuminated by luminous rays proceeding from a point 1.7 m. distant from the centre of the disk; at what distance will the shadow have a diameter of 3.4 m.? (B.)

1313. A square plate, each side 0.25 m. long, is held in front of the eye, 50 centimeters from the eye; find the area which, at a distance of 200 meters, is concealed by this plate.

1314. Light issues from a luminous globe 12 inches in diameter, and falls upon a second, opaque, globe 6 inches in diameter; show by a diagram the kind of shadow cast by the latter. (T.)

1315. A cloud is composed of transparent water particles; but if transparent, why are clouds able to intercept so much of the sun's light? (T.)

1316. Define the difference between the forms of a tree (1), when the tree stands in the sunshine and throws its form upon the ground; (2), when the tree stands near still water and its form is seen in the water.

1317. What is the velocity of light, and how has it been ascertained? (T.)

1318. Describe and explain Bunsen's photometer.

1319. I wish to compare the light of a candle flame with that of a gas flame of the same size. How would you determine and express numerically the relative intensities of the two lights? (T.)

1320. State what you know regarding the intensity of light.

1321. By what means do we ascertain that one light has 8 or 10, or any other number of, times the intensity of another?

1322. In what ratio is a book illuminated if, first, it is 0.25 m. distant from the source of light, and next 1.75 m. distant?

1323. In order to compare the light of a petroleum lamp with that of a tallow candle, both were so placed as to throw shadows of equal intensities on a wall; the distance between the lamp and the wall was 5 feet, that of the candle and the wall 1 foot. Give the ratio of their intensities.

1324. Work the preceding example, the lamp being 2 m. and the candle 0.2 m. from the same wall.

REFLECTION.

1329. Distinguish between *radiant* and *specular* reflection.

1330. State the laws of the reflection of light.

1331. The sun is 30° above the horizon, and you see his image in a tranquil pool; what, in this case, is the angle of incidence and reflection? (T.)

1332. Show by a diagram the position of the image of an erect object as seen in a mirror inclined 45° to the horizon.

1333. You hold a candle before a glass window so that its rays fall nearly perpendicularly upon the glass, and place your eye so as to receive the reflected rays; two images of the candle are visible. Why only two? (T.)

1334. Given three points, 1, 2 and 3, not lying in a straight line. Show by a diagram how you would place a mirror at point 3, so as to have a ray proceeding from 1 reflected to 2.

1335. Find the number of images seen reflected in a kaleidoscope whose two mirrors incline to each other at an angle of 36°.

1336. Two mirrors are inclined to each other at an angle of 60°. Construct the images resulting from a luminous point between the mirrors.

1337. An arrow is placed in front of a concave mirror. Construct its image if the arrow is placed (1) beyond the center of the sphere; (2), at the centre; (3), between centre and principal focus; (4), at the principal focus; (5), between the principal focus and the surface of the mirror.

1338. Distinguish between a *real* and a *virtual* image.

1339. Explain the formation of a real image by a concave mirror.

1340. A large concave mirror is placed before you; you see your image first inverted in the air; you change your distance from the mirror, and find that in a certain position your image vanishes; again, you change your position and find your image erect. Under what circumstances are these effects observed? State whether the images observed are of greater or less size than yourself, and give the reason of the increase or diminution. (T.)

1341. When an image is formed by a concave mirror, in certain positions you see the image in the air, while in certain other positions you do not see it. If, however, a sheet of tracing paper receive the image, it is seen from positions, before and behind, in which the ærial image was invisible. Explain all this. (T.)

1342. I place a candle in front of a convex mirror. Construct the image, and explain the conditions of the image.

1343. Describe and show by a diagram the character of the image formed by a convex mirror. (T.)

1344. Describe and explain the character of the images formed by a concave mirror. Why do I employ the term *image* in the previous question, and the term *images* in this one? (T.)

1345. What is meant by total reflection?

1346. Describe the circumstances under which total reflection takes place.

1347. A white towel spread on a table has water sprinkled upon it; the parts on which there is water look darker; but if you look at a light through the towel the wet parts seem brightest. Explain this.

1348. Why are the colors of a diamond more brilliant than those of a piece of glass cut after the same pattern?

REFRACTION—THE EYE—VISION.

1354. Define refraction, and illustrate by an example.

1355. State the laws of refraction.

1356. What is meant by the index of refraction?

1357. Why should a lake, the bottom of which you can see, appear shallower than it really is? (T.)

1358. I fill two cups of the same depth with two different liquids, and notice two things: firstly, both cups appear shallower than when they were empty; and secondly, one of them appears shallower than the other. Explain. (T.)

1359. Show by a diagram the manner in which a stick appears bent when it is thrust obliquely into water. Explain the appearance. (T.)

1360. When a ray of light is refracted through a window-pane, the exit ray is parallel to the incident ray. Why?

1361. State the likeness that exists between light and radiant heat as regards reflection, refraction and transmission.

1362. What effect has the greater or less thickness of a glass plate upon the displacement of objects seen through it?

1363. Show by a diagram the course of a ray of light passing through a sphere of solid glass without striking the centre of the sphere.

1364. Describe a prism, and show by a diagram how it acts upon light. (T.)

1365. Draw a section of a prism; draw also the section of a beam of sunlight passing through the prism, and show by your sketch how this light is acted upon by the prism. (T.)

1366. Describe some experimental mode of determining the index of refraction of a transparent liquid. (T.)

1367. What are lenses? What is their purpose?

1368. Into how many kinds do lenses divide themselves?

1369. What is meant by the principal focus, and the main axis of a lens?

1370. State four cases of refraction through a convex lens.

1371. Describe the manner in which images are formed by a convex lens. (T.)

1372. Describe and explain the camera obscura.

1373. Show by a diagram the course of a ray of light falling (parallel to the main axis) upon a double convex lens.

1374. Show by a diagram the course of a ray of light striking (parallel to the main axis) a plano-convex lens.

1375. Show by a diagram the course of a ray of light striking (parallel to the main axis) the convex side of a concavo-convex lens.

1376. Show by a diagram the course of a ray of light falling upon a double convex lens of equal radii and small thickness, and starting

a. From beyond the principal focus.

b. From the principal focus.

c. From between the principal focus and the lens.

1377. Show by a diagram the condition and position of images formed by an object situated respectively at *a*, *b* and *c* in the preceding example.

1378. Show the likeness that exists between sound and light as regards reflection and refraction. (T.)

1379. How is the linear magnifying power of a single bi-convex lens found?

1380. What is the magnifying power of a bi-convex lens of $\frac{3}{8}$ inch focal distance, the mean distance of distinct vision being 10 inches?

1381. Of what ratio are the magnifying powers of the bi-convex lens in the preceding example, for a near-sighted per-

son whose average distance of distinct vision is 0.2 m.? For a person whose distance of distinct vision = 0.4 m.?

1382. What would be the advantage or disadvantage of a diamond lens in a microscope?

1383. What is the magnifying power of a system of two lenses, having a focal distance of ¾ inch each, and being placed ⅜ inch apart?

1384. What is the magnifying power of a microscope whose focal distance=0.0125 m.? (Assume 1 m.=40 inches).

1385. State what you know regarding the form and use of spectacles. (T.)

1386. I am long-sighted and use spectacles, each glass of which is formed of two segments, one intended to give sharpness to distant objects, the other for ordinary reading; describe the character of both glasses, and explain how they help the eye. (T.)

1387. Explain the construction of the common opera glass. (T.)

1388. Describe and explain some one form of the reflecting telescope (T.)

1389. Describe some one form of the refracting telescope. (T.)

1390. Show by a diagram the course of a ray of light striking, parallel to the main axis, a double concave lens with equal radii.

1391. Show by a diagram the course of a ray of light, striking parallel to the main axis, the curve of a plano-concave lens.

1392. Construct the image of an object which is at some distance from a bi-concave lens.

1393. A ray of light falls obliquely upon a thick plate of glass and thence is supposed to pass through different media

in succession, viz., through a layer of chlorine gas, next through a film of water, one of alcohol, one of bisulphide of carbon, and lastly through air again. Trace its path throughout these media.

1394. Show by a diagram the spherical aberration of a concave mirror.

1395. State what you know regarding the structure of the human eye. (T.)

1396. What is meant by the distance of distinct vision?

1397. Describe the human eye, and state the conditions which must be fulfilled to render vision distinct.

1398. What is meant by the adjustment of the eye for distinct vision at different distances, and how is the adjustment accomplished?

1399. What is meant by the visual angle?

1400. Define irradiation.

1401. What form of lenses do you consider most useful for a diver? State the reason.

1402. Why is the human eye not adapted for vision under water?

COLORS, ETC.

1407. What is meant by the dispersion of light?

1408. What is the difference between the "scattering" of light and the "dispersion" of light?

1409 Describe the solar spectrum. How may it be produced?

1410. Describe clearly an experiment by which white light can be resolved into the differently colored lights which compose the white. Describe also an experiment by which the colors can be recompounded. (T.)

1411. What are the colors of the spectrum?

1412. What are the properties of the spectrum?

1413. Show that color may be compared to *pitch* in sound.

1414. Define color.

1415. When is a body black; when white?

1416. Looking through a red glass at the white body of the sun you see it red; in what way does the red glass act upon the light so as to produce this impression? (T.)

1417. Why is a rose red, and grass, green? (T.)

1418. How are the colors of flowers produced? (T.)

1419. You enter a room by daylight and find the walls covered with vividly colored paper; you close the windows so as to reduce the room to total darkness; are the colors still there? Give a full reason for your answer. (T.)

1420. The length of a wave of yellow light is 0.0002528 of a line; find the number of such waves striking the retina per second. (A line is the twelfth part of an inch.)

1421. The average length of a wave of white light is 0.0002368 of a line; find the number of waves per second.

1422. Sunlight falls on a surface painted red; a portion of the light is reflected from the surface; what is the color of this portion? A portion enters the paint; what becomes of it? (T.)

1423. State what occurs within a black body which renders it black; and state what occurs within a white body which renders it white. (T.)

1424. A spectrum cast upon a white screen is looked at through a purple glass; what appearance does it present, and what is the cause of this appearance? (T.)

1425. I place a red ribbon successively in the green and the red of the spectrum; how is its temperature affected? I do the same with a green ribbon; how is its temperature affected? (T.)

1426. What are complementary colors? Give a list of them.

1427. What is an achromatic lens?

1428. What is meant by the *dispersion* of light? State what you know regarding achromatism.

1429. The rays of the sun are received upon a large converging lens; a screen placed within the focus shows a white circle surrounded by a red fringe; if placed beyond the focus it shows a white circle surrounded by a blue fringe. Explain these appearances. (T.)

1430. State what you know regarding the lines of Fraunhofer. (T.)

1431. Describe and explain the lines of Fraunhofer, and deduce from them a theory of the composition and temperature of the sun. (T.)

1432. Describe an experiment which shall illustrate the chromatic aberration of a lens. (T.)

1433. Define spectrum analysis.

1434. How is the primary rainbow produced?

1435. How is the secondary rainbow produced?

1436. What is meant by diffraction?

1437. Explain double refraction.

1438. Define polarization of light.

1439. Describe the polarization of light by reflection, by refraction, and by double refraction; and assign the conditions necessary to render the polarization complete. (T.)

1440. Define the terms *Calorescence*, *Fluorescence*, *Inter-*

MAGNETISM.

1445. Define magnetism.

1446. What is a magnet? What is a magnetic body?

1447. What is a load-stone? Mention four magnetic substances.

1448. Distinguish between natural and artificial magnets.

1449. What is meant by the poles of a magnet? By the polarity of a magnet? May a bar magnet have more than two poles?

1450. What is meant by the poles of a magnet?

1451. Can you obtain a magnet with a single pole? Give the experimental grounds of your answer. (T.)

1452. You break a magnet in two; what are the magnetic conditions of its parts?

1453. State the grounds of the belief that the smallest particles of a magnet are themselves perfect magnets. (T.)

1454. Sketch a bar-magnet and letter its poles; show by dotted lines the manner in which iron-filings arrange themselves round the bar-magnet. Do the same for a horse-shoe magnet.

1455. Place two bar-magnets side by side, parallel to each other, with their north poles turned in the same direction; show by a sketch how filings scattered over the two magnets will arrange themselves. (T.)

1456. What is the neutral line of a magnet?

1457. State the law of magnetic attraction and repulsion.

1458. How would you demonstrate the preceding law?

1459. Explain the terms *paramagnetic* and *diamagnetic*.

1460. Five balls of iron hang in a series from the north end of a magnet, but you cannot get a sixth ball to hang; why? The north end of a second magnet is brought *over* that of the first; seven balls of iron now cling together; why? You place the second north pole *below* the series of balls; several of them fall away. Explain this.

1461. Distinguish between *permanent* and *temporary* magnets.

1462. What is the keeper or armature of a magnet?

1463. What effect has heat upon magnets?

1464. You are required to magnetize a sewing needle so as to make the eye of the needle a north pole; how will you do it? The point of the needle is then presented to the north end of a mariner's compass needle; what will occur?

1465. What is the difference between iron and steel as regards their acceptance and their retention of the magnetic condition? (T.)

1466. Mention three modes of magnetizing steel bars.

1467. The pole of a magnet is drawn over an unmagnetized bar of steel; state in the language of the theory of magnetic fluids what occurs. (T.)

1468. What is meant by the coercive force of magnets?

1469. How would you demonstrate magnetic induction?

1470. What does terrestrial magnetism imply?

1471. State any one theory of magnetism.

1472. A bar of iron is held vertical, and a magnetic needle is passed slowly from its bottom to its top; describe the action of the iron upon the needle. What is the effect of reversing the bar? (T.)

1473. What is meant by magnetic declination?

1474. State what you know regarding the action of the

earth upon a freely suspended magnet? Illustrate the earth's action by means of a bar-magnet.

1475. What is meant by magnetic inclination or dip?

1476. What is meant by the declination and inclination of the magnetic needle? What is meant by the terms magnetic dip, magnetic poles, and magnetic equator? (T.)

1477. What do you think causes a magnetic needle to set north and south? Does its direction ever vary? If so, state what you know regarding the variation. (T.)

1478. State what you know regarding the use of the magnetic needle in the steering of ships. (T.)

1479. The marked end of a magnet is attracted by the earth's north magnetic pole; but if the magnet be set floating on a cork it does not move toward the pole. Why? (T.)

1480. What is the meaning of the term geographical meridian? What is the meaning of magnetic meridian? What name is given to the angle between the two meridians? (T.)

1481. A bar-magnet, freely suspended horizontally, sets in the magnet meridian. Supposing a second bar-magnet to be suspended by the side of the first, how will they act upon each other? Make your answer clear by a diagram. (T.)

1482. You carry with you a dipping needle from the earth's north magnetic pole across the equator to the south magnetic pole; how will the dipping needle behave during this excursion? (T.)

1483. How would you demonstrate that the earth behaves like a magnet?

1484. How am I to hold an iron bar so that it shall receive its maximum of magnetization from the earth? How, when held in this position, is such a bar to be tested?

1485. Give the law of magnetic intensity.

1486. How may magnetic force be measured?

1487. A small magnetic needle freely suspended, and acted upon by the earth alone, executes 120 vibrations in a minute; placed near the pole of a steel magnet it oscillates 250 times in a minute; compare the force which the earth exerts upon the needle with that exerted by the magnetic pole, and give the numbers which express the forces. (T.)

1488. You have two bar-magnets of different powers, and a small magnetic needle. You are required to determine and express numerically the relative powers of the two magnets. How will you do it? (T.)

1489. A magnetic needle is placed obliquely to the magnetic meridian; show by a sketch the character of the forces acting upon the needle, and tending to turn it into the meridian. (T.)

1490. You hear of the magnetic meridian and of the geographical meridian; what is the difference between them? To what changes, if any, have they been observed to be subject? (T.)

1491. The end of a magnetic needle brought near the middle of a bar-magnet is, to all appearance, not acted upon at all by the magnet. Does the magnet really exercise no action on the needle in this position? If so, what action? (T.)

FRICTIONAL ELECTRICITY.

1501. What is frictional electricity? State its sources.

1502. Mention some simple means of exciting electricity by friction.

1503. If a quantity of mercury in a dry glass be connected, by a wire, with a gold leaf electroscope, and a dry rod of glass be immersed in it, what is observed if it be left there, and also when the rod is gradually withdrawn? (M.)

1504. Name some substances that seem incapable of receiving electric excitement by friction.

1505. I wish you to show me a few simple electrical effects; how will you do it? (T.)

1506. If, upon a warm board, a dry sheet of paper be rubbed with india-rubber, it is electrified. How is this proved? (T.)

1507. Can electric phenomena be produced in *vacuo*, or in an atmosphere of *carbonic acid gas*?

1508. Show by a simple experiment that the electricity developed on resin by the friction of flannel is different from that developed on glass by the friction of silk. (T.)

1509. I wish you to prove that like electricities repel each other, and that unlike electricities attract each other.

1510. A strip of paper rubbed with india-rubber is brought near a glass rod which has been rubbed with silk; what follows? Deduce from the experiment the quality of the electricity upon the paper. (T.)

1511. Explain fully what takes place when light bodies are attracted by a stick of sealing-wax rubbed with flannel. (T.)

1512. When you think of an electrified body, in what way do you picture it to your mind? (T.)

1513. A collodion balloon simply stroked with the hand becomes negatively electrified. Supposing you were asked to prove the truth of this statement, how would you proceed? (T.)

1514. An egg-shell is placed on a table, and a glass rod which has been rubbed with silk is brought near the shell; the shell rolls after the rod. Describe the condition of the rod and the shell during the motion of the latter. (T.)

1515. If you take an insulator in your hand and rub it properly you electrify it; if you do the same with a conductor you obtain no signs of electricity; what is the reason? Bodies were formerly divided into electrics and non-electrics; why? (T.)

1516. Can a solid body be electrified by friction with a liquid or gas? If so, mention an instance of each.

1517. When is water a bad conductor of electricity?

1518. Distinguish between conductors and non-conductors of electricity. Is this distinction absolute?

1519. Mention three conducting substances and three non-conducting ones.

1520. When is air a good conductor of electricity?

1521. Mention two causes why electrified bodies, even when placed on insulators, gradually lose their electricity.

1522. Has climate any influence on insulators? Illustrate by glass.

1523. If you rub a stick of sealing-wax held in the hand with flannel, it becomes electrified; if you rub a rod of brass, you do not electrify it. What is the reason of this difference? (T.)

1524. What happens when two conducting bodies are brought in contact with each other, the one being electrified, the other not?

1525. How is the conductivity of glass altered when the glass is heated to redness?

1526. Two strings are given to you, and you are required to test whether they insulate or conduct electricity; how will you proceed? (T.)

1527. Prove that there are two kinds of electricity.

1528. What do the signs + and — mean in electricity?

1529. Why is repulsion a surer test of the electric condition of a body than attraction?

1530. When two bodies are rubbed together, which of the two kinds of electricities is generated first?

1531. Mention three substances arranged in such an order that of the first two each becomes positively electrified when rubbed with the body following, and that the last becomes negatively electrified when rubbed with the substance preceding.

1532. When you rub a stick of sealing-wax with flannel, what is the state of the rubber? When you rub a stick of glass with silk, what is the state of the rubber? (T.)

1533. If two persons stand, each on an insulating stool, and one strike the other with a well-dried cat's fur several times, which of them will be *positively* electrified, and which *negatively?*

1534. What is meant by the term "insulated?" I bring a glass rod which has been rubbed with silk near an insulated

brass sphere; what is the condition of the sphere while the glass is near it? What occurs when the glass is removed? (T.)

1535. State the laws of frictional electricity.

1536. What is an electroscope? What an electronomer?

1537. I grind sulphur in a mortar and thus electrify it. I place some of the electrified powder on the plate of a gold-leaf electroscope; the leaves diverge; why? since the sulphur is an insulator and does not part with its electricity. I remove the powder by means of an insulator; what will occur, and why will it occur? (T.)

1538. Describe an experiment to prove that free statical electricity shows itself only on the surface of bodies.

1539. Does the form of a body exert any influence on the accumulation of electricity? (T.)

1540. Two insulated conductors, of the same size, and charged with unlike electricities, attract each other with a certain amount of force or tension. Find the relative amount of this force when each conductor is charged with six times the previous quantity of electricity? Answer: 36.

1541. Two insulated conductors, of the same size, and charged with like electricities, repel each other with a certain amount of force. Find the amount of the force when one of the conductors is charged with $3\frac{1}{2}$ times, the other with $5\frac{1}{2}$ times the previous quantity of electricity.

1542. Two insulated conductors, of the same size, and charged with like electricities, repel each other with a certain amount of force. Each is then charged with three times the previous quantity of electricity. How many times as far must they now be apart from each other, in order that the force of repulsion remain the same as before?

1543. What amount of repulsive or attractive force will be

exerted by an electrical quantity of 8 upon one of 6 at a distance of 4?

1544. Two insulated conductors have surfaces of 100 and 150 square centimeters, respectively, and are charged each with the same quantity of electricity. Find the ratio of their electric densities.

1545. A sphere of 4 inch diam. receives the same quantity of electricity as one of 5 inch diameter. Find the ratio of their electric densities.

1546. Find the ratio of the densities of electricity on two spheres, one of which, A, has a diameter of 3 inch., the other, B, a diameter of 4 inch. with three times the quantity of electricity.

1547. Describe the action of any electrical machine.

1548. State two uses of an electrical machine.

1549. You stand on an insulator and place one hand on the prime conductor, the other over an open gas burner. The machine is then worked, and the gas is lighted. Explain this.

1550. What reason have we for alluding to the earth as a *common reservoir* of electricity?

1551. Describe an experiment illustrating electric induction.

1552. What is meant by electric induction?

1553. What does electric induction depend upon?

1554. Describe Franklin's plate, and explain its action.

1555. Describe and explain the original experiment which led to the discovery of the Leyden jar. (T.)

1556. Two insulated metal spheres are united by a chain; a body positively electrified is placed near one of them; what is the condition of the other? You touch the sphere adjacent to the electrified body; what occurs? Finally you remove the electric body; what occurs? (T.)

1557. Explain the common mode of charging a Leyden jar.

1558. Define electric density, electric tension, and electric intensity.

1559. What is an electric condenser? Illustrate its use.

1560. You are provided with a sheet of vulcanized India-rubber and two sheets of tin-foil, and are required to arrange them so as to obtain from them a shock similar to that of a Leyden jar. How will you do it? (T.)

1561. On a sheet of tin-foil I lay a plate of glass which can be lifted by means of loops; and on the glass I lay a second sheet of tin-foil. The lower sheet is connected with the earth, and the upper one with the conductor of an electric machine, and also with a gold-leaf electroscope. I turn the machine carefully, and find the amount of turning necessary to cause the gold leaves to diverge greater than when the conductor and the electroscope are connected without the intervention of the sheets of tin-foil. Explain this. I also find that, when the glass and the upper sheet are lifted from the lower one, the gold leaves suddenly diverge. Why? (T.)

1562. A Leyden jar is hung up in the air by a silk string; the knob of the jar is connected with an electric machine, and its outer coating is connected by a wire with a large gas pipe. What occurs in this outer wire when the machine is worked, and why does it occur? (T.)

1563. Why do I employ a silk string to suspend the jar in the last experiment? What would happen, supposing the string to be ordinary twine? (T.)

1564. You are provided with an electric machine and a battery of ten Leyden jars, and are required to charge and discharge the battery; how will you proceed? Describe some of the effects and appearances of the electric discharge. (T.)

1565. In charging a Leyden jar, some time ago, I heard a crack. An electrometer attached to the conductor of the machine instantly fell, and showed no further signs of electricity. When the jar was examined it was found perforated. Explain these effects. (T.)

1566. You hold the knob of a Leyden jar against the conductor of an electric machine, and stand on one foot upon an insulating stool, placing the other foot on the knob of a Leyden jar which stands on the earth. State exactly what occurs when the machine is worked. (T.)

1567. I furnish you with two Leyden jars, and ask you to charge one of them in the usual way; how will you proceed? I then ask you to charge the second jar by electricity from the external coating of the first. How is this electricity generated, and what arrangement will you make to send it into the second jar? (T.)

1568. Describe an experiment to prove that when a Leyden jar is charged with positive electricity, positive electricity escapes from the outer coating of the jar. (T.)

1569. A needle is attached to a prime conductor, so as to project from it, of an electric machine. Why is it that the sparks are shorter than when the needle is absent?

1570. Explain the action of electrified points. (T.)

1571. A bundle of cotton wool is hung by a common thread from the conductor of an electric machine, and then electrified. I present my closed hand, which contains a sewing needle within it, to the wool; the wool is attracted. I now open my hand so as to uncover the point of the needle; the wool is repelled. Why? Connect this action with that of a lightning conductor upon a cloud. (T.)

1572. Name some of the changes on which atmospheric electricity depends.

1573. What is lightning?

1574. What may be considered the safest positions during a thunder storm?

1575. Describe and explain Franklin's experiment with the kite, by which he demonstrated the existence of atmospheric electricity. (T.)

1576. What influence may atmospheric electricity have on the wires of the electric telegraph?

1577. What are the purposes of lightning rods?

1578. A common prejudice against lightning rods may be stated thus: Lightning rods invite the electric fluid and, with it, also its damages. How will you refute it?

1579. Describe the action of a pointed lightning conductor on a cloud charged with positive electricity.

CHEMICAL ELECTRICITY.

(GALVANIC, VOLTAIC, OR DYNAMIC.)

1581. Mention the nature of conductors for this kind of electricity.

1582. Explain what you understand by the direction of a voltaic current.

1583. What is the source of the electric current?

1584. Define electromotive force, and tell on what the amount of work done depends.

1585. I place a bit of silver on my tongue, and a bit of zinc under it, and cause the two pieces of metal to touch each other; what occurs? Describe some means of proving that an electric current is generated. (T.)

1586. Distinguish between frictional and chemical electricity.

1587. Describe the Voltaic Pile.

1588. A current means something flowing. What is it that flows in the voltaic current: is it anything that you can see, or feel, or taste, or smell? If not, what proof have you of its existence? (T.)

1589. What are electrodes and what are electrolytes?

1590. What happens when a strip of zinc is plunged into water?

1591. What happens when a strip of zinc and copper are placed disconnected in the same body of water?

1592. What happens when the same strips are in water, disconnected, but the zinc has a conductor soldered to it, connecting it with the copper?

1593. I dip a strip of pure platinum and of pure zinc into water which has been rendered sour by sulphuric acid. State what occurs when the metals do not touch each other, and also what occurs when they do touch each other. (T.)

1594. Supposing the two strips to be half in the sour water and half out of it, and that their two outer ends are united by a wire, what occurs? (See preceding example.) (T.)

1595. What law holds good of a series of cells, or of the electro-motive force in general?

1596. What is meant by contact-electricity?

1597. Of potassium, zinc, iron, copper, gold, which become positive when in contact with tin and silver, and which become negative?

1598. Describe the Sand battery.

1599. Describe Smee's battery, and tell how Walker's differs from it.

1600. State three defects of single-fluid batteries.

1601. Tell clearly what is meant by a two-fluid battery.

1602. Describe Daniell's battery.

1603. Describe Marie Davy's battery.

1604. Give a sketch of a cell of Grove's battery, and state the uses of its various parts.

1605. What is the part played by the nitric acid in Grove's battery?

1606. Describe the bi-chromate battery.

1607. Describe Leclanché's cell.

1608. I give you platinum, zinc and brine, and ask

you to produce, by means of them, an electric current; how will you do it? (T.)

1609. What are the chief merits of a galvanic cell?

1610. What does the *strength* of a galvanic cell depend upon?

1611. Platinum is a bad, silver a good, conductor of electricity; which of the two offers the greater resistance to a current?

1612. The same electric current is sent in succession through two spirals of platinum wire Both feel warm to the hand. You then heat one of the spirals to bright redness with a spirit lamp. What is the effect upon the temperature of the other? (T.)

1613. Suppose that, in the previous example, instead of heating one of the wires by means of a spirit lamp, you had cooled it with ice. What would have happened?

1614. Give the law of electric *resistance;* also state it by an equation.

1615. The same current from a Grove's battery is sent through two pieces of wire, one of silver, the other of platinum, of the same length and thickness. The silver remains cool, the platinum is heated to redness. Why? (T.)

1616. Give Ohm's law.

1617. What does the thermo-electric current depend upon?

1618. How will you produce a thermo-electric current? (T.)

1619. Define and describe a galvanometer.

1620. What is an astatic galvanometer (or the astatic needle)?

1621. State the four cases in which an electric current may deflect a magnetic needle.

1622. You wish to convert a poker into an electro-magnet, with its knob as a north-pole. Show by a sketch how it is to be done. (T.)

1623. What are the principles of the electric telegraph?

1624. In what particulars does an electro-magnet differ from an ordinary steel magnet?

1625. You are required to prove that a current of electricity is passing through a telegraphic wire to which you have access. (T.)

1626. What are the effects of chemical electricity?

1627. Explain and illustrate the "thermal" effects of chemical electricity. Are these confined to thin wire, or may they occur also in thick wire?

1628. You are required to fire gunpowder by means of a voltaic current; how will you proceed?

1629. Explain the principles of the electric lamp, and state in the explanation how the two carbon points are affected by the passage of the current. (T.)

1630. A voltaic current is sent through water, the water is decomposed and two gases formed; what are they, and where do they make their appearance? (T.)

1631. If a strong voltaic current is sent in succession through a thin platinum wire through acidulated water, and then through a wire which surrounds a common poker, what is the effect produced in each case? (T.)

1632. A glass cell contains a solution of common table salt, colored by indigo. A voltaic current is sent through the solution, the blue color is observed to grow gradually paler, and finally to disappear; explain this effect. (T.)

1633. Describe and illustrate by an example the process of electrotyping.

1634. Define electrolysis.

1635. Describe the action of a voltaic current—1st, on iron filings; 2d, on a bar of iron; 3d, on a freely suspended magnetic needle; 4th, on a second voltaic current. (T.)

1636. State three cases of currents acting on currents.

1637. What is meant by a solenoid?

1638. Describe the action of magnets on currents.

1639. Explain the induction of currents.

1640. Describe a Ruhmkorff's coil.

1641. What difference exists between a *primary* and a *secondary* coil, and through which of them is the current passed?

1642. What is meant by magneto-electricity? Give some illustrations of its development.

1643. Explain the telephone.

1644. In the common medical coil there is usually an iron core surrounded by a thick wire, and around this a bobbin of fine wire to which handles are attached. Now this fine wire is wholly detached from the thick one, and also from the exciting battery; how, then, are shocks experienced when the two handles are grasped and the machine is set in action? (T.)

1645. Two voltaic currents are sent in opposite directions round the same magnetic needle; the needle points to zero. What do you infer? One of the currents passes through and heats a platinum wire. On blowing upon this wire and cooling it, the needle immediately starts aside. Explain this. (T.)

APPENDIX.

I.—THE METRIC SYSTEM OF WEIGHTS AND MEASURES.

I.—MEASURES OF LENGTH.

BASE.—1 Meter=39.37079 inches, nearly.

TABLE.		THE TABLE IS THUS READ.
Ascend'g Scale.	1 Myriameter.	10 Millimeters make 1 centimeter.
	1 Kilometer.	10 Centimeter " 1 decimeter.
	1 Hectometer.	10 Decimeters " 1 *meter.*
	1 Decimeter.	10 Meters " 1 decameter.
	1 *Meter*—Unit.	10 Decameters " 1 hectometer.
Descend'g Scale.	1 Decimeter.	10 Hectometers " 1 kilometer.
	1 Centimeter.	10 Kilometers " 1 myriameter.
	1 Millimeter.	

One foot=0·3047945 meter. One centimeter=0.3937079 inch.

II.—MEASURES OF SURFACE, OR SQUARE MEASURE.

BASE.—1 Are=the square whose side is 10 meters
=119.6 square yards, nearly,
=4 perches or square rods, nearly.

TABLE.	THE TABLE IS THUS READ.
1 Hectare.	1 Hectare makes 100 ares.
1 *Are*—Unit.	1 Are " 100 centiares.
1 Centiare.	

1 Square centim.=0.155 square inch.
1 Square inch=6.4516 sq. cent.
1 Square foot=9.2899683 sq. decim.
1 Square yard=0.83609715 sq. meter.

III.—MEASURES OF VOLUME.

BASE.—1 Liter=the cube on the decimeter=1000 c. c.
=61·027+cubic inches,
=a little more than a wine quart.

	TABLE.	THE TABLE IS THUS READ.
Ascending Scale.	1 Kiloliter.	10 Milliliters make 1 centiliter.
	1 Hectoliter.	10 Centiliters " 1 deciliter.
	1 Decaliter.	10 Decoliters " 1 *liter*—1000 cubic centim.
	1 *Liter*—Unit.	10 Liters " 1 decaliter.
Descending Scale.	1 Deciliter.	10 Decoliters " 1 hectoliter.
	1 Centiliter.	10 Hectoliters " 1 kilioliter, or stere.
	1 Milliliter.	

1 Gallon=4.54345797 liters=277.25 cub. in.
1 Cubic inch=16.386176 cb. cen.
1 Cubic foot=28.315312 cb. decim.

IV.—MEASURES OF WEIGHT.

BASE.—1 Gram=weight of a cubic centimeter of distilled water at 4°C.
=15·432 grains Troy, nearly.
=0·0352746 ounces Avoirdupois, nearly.

TABLE.	TABLE IS THUS READ.
1 Millier, or tonneau.	10 Milligrams make 1 centigram.
1 Quintal.	10 Centigrams " 1 decigram.
1 Myriagram.	10 Decigrams " 1 gram.
1 Kilogram, 2.2046 pds. Avdps.	10 Grams " 1 decagram.
1 Hectogram.	10 Decagrams " 1 hectogram.
1 Decagram.	10 Hectograms " 1 kilogram.
1 *Gram*—Unit.	10 Kilograms " 1 myriagram.
1 Decigram.	10 Myriagrams " 1 quintal.
1 Centigram.	10 Quintals " 1 millier or tonn.
1 Milligram.	

One pound Avoirdupois=0.45359265 kilo.

TABLE OF VELOCITIES (PER SECOND).

Man walking rapidly	1.8	meters.
Horse galloping, from 4 to	5	"
Railway train, 8 to	18	"
Vessels, 3 to	7	"
Winds and storms, from 3 to 30 and	40	"
Rifle-ball	500	"
24-pound ball	800	"
Sound	333	"
Light (approximately)	315000	kilom.
Electricity (on copper conductors)	460000	"

TABLE OF SPECIFIC GRAVITIES.

(*Temperature of substances*=0° *C.*—*The numbers given are sufficiently accurate for practical purposes.*)

SOLIDS.

Platinum	22.0	Plate Glass	2.40
Gold	19.3	Limestone	2.80
Mercury	13.6	Sandstone	2.40
Lead	11.0	Quartz	2.65
Silver	10.5	Bitum. Coal	nearly, 1.40
Copper	8.8	Gypsum	2.30
Brass	8.4	Common Salt	2.10
Steel	7.8	Sulphur	2.00
Wrought Iron	7.8	Ivory	1.90
Cast Iron	7.2	Amber	1.00
Tin	7.3	Wax	0.97
Zinc	7.2	Ice	0.88
Antimony	6.7	Ebony	1.23
Iodine (solid)	5.0	Oak Wood	1.17
Heavy Spar	4.43	Maple Wood	0.90
Diamond	3.50	Pine Wood	0.70
Flint Glass	3.44	Poplar Wood	0.40
Crown Glass	2.90	Cork Wood	0.25
Ordinary Glass	2.60		

LIQUIDS.

Bromine	3.00
Sulphuric Acid	1.85
Nitric Acid	1.50
Muriatic Acid	1.20
Hydrochloric Acid	1.20
Carbon Disulphide	1.27
Glycerin	1.25
Milk	1.03
Ocean Water	1.03
Oil of Turpentine	0.86
Linseed Oil	0.95
Petroleum	0.84
Alcohol (absolute)	0.79
Ether	0.71

GASES.

Iodine Vapors	6.60
Sulphur Vapors	6.60
Mercury Vapors	7.00
Chlorine Gas	2.45
Hydrofluoric Acid	2.37
Sulphurous Acid	2.25
Carbonic Acid Gas	1.50
Oxygen	1.10
Air	1.00
Nitrogen	0.97
Ammonia	0.60
Water Vapor	0.62
Illuminating Gas	0.60
Hydrogen	0.07

CONDUCTION OF HEAT.

METALS.	THERMAL CONDUCTIVITY IN VACUO. (*Wiedeman & Frans.*)
Silver	100.0
Copper	74.8
Gold	54.8
Brass	24.0
Tin	15.4
Iron	10.1
Steel	10.3
Platinum	9.4
Lead	7.9

Organic substances have a low power of conduction.

REMARKABLE TEMPERATURES (DEGR. C).

Greatest artificial cold	140	degrees.
Mercury freezes	39.4	"
Ice melts	0	"
Greatest density of water	4	"
Blood heat	36.6	"
Water boils	100	"
Red heat	526	"
Cast iron melts	1530	"

COEFF. OF LINEAR AND CUBICAL EXPANSION.

	Linear Mean for 1° *Centigrade* (*between* 1° *and* 100°).	*Cubical Mean for* 1° *Centigrade* (*between* 1° *and* 100°)
Iron	0.0000118	0.000036
Steel	0.0000124	
Platinum	0.0000080	
Glass	0.0000085	0.000025
Copper	0.0000170	0.000051
Lead	0.0000290	0.000089
Tin	0.0000217	0.000069
Zinc	0.0000290	0.000089
Gold	0.0000145	

EXPANSION OF MERCURY AND WATER.

Temperature C°.	*Vol. of Merc.=Unity at 0°.*	*Vol. of Water—Unity at 4°C=39° F.*
0	1.000000	1.00013
4		1.00000
10	1.001792	1.00027
20	1.003590	1.00179
30	1.005393	1.00433
40	1.007201	1.00773
50	1.009013	1.01205
60	1.010831	1.01698
70	1.012655	1.02255
80	1.014482	1.02885
90	1.016315	1.03566
100	1.018153	1.04315
150	1.027419	
200	1.036811	
250	1.046329	
300	1.055973	
350	1.065743	

Vol. at 100° C (unity at 0° C) of	
Alcohol	1.111
Hydrochl'ic Acid.	1.037

MELTING POINTS (DEGR. C).

Solid Carb. Acid....	−87 deg.	Zinc.....	423 deg.		
Mercury.....	−39 "	Silver ...	1000 "		
Phosphorus.....	43 "	Copper...	1090 "		
Sulphur.....	109 "	Gold.....	1250 "		
Tin.....	228 "	Iron.....	1600 "		
Lead.....	325 "	Platinum.	2500(?)"		

BOILING POINTS (DEGR. C).

Alcohol..	79 deg.
Water...	100 "
Mercury.	350 "
Zinc.....	1040 "

LATENT HEAT.

Substance (1 *Kilogram*).		*Vapors* (*equal weights; steam*=1).	
Water	1.000	Water	1.000
Phosphorus	0.063	Wood Spirit	0.492
Sulphur	0.118	Alcohol	0.378
Nitrate of Soda	0.794	Ether	0.169
Nitrate of Potass	0.598	Bisulphide of Carbon	0.162
Tin	0.179	Oxalic Ether	0.136
Bismuth	0.159	Formic Ether	0.196
Lead	0.067	Acetic Ether	0.173
Zinc	0.355	Iodide of Ethyl	0.087
Cadmium	0.172	Iodide of Methyl	0.086
Silver	0.266	Bromine	0.085
Mercury	0.035	Perchloride of Tin	0.057
		Formiate of Methyl	0.219
		Acetate of Methyl	0.206
		Perchloride of Phosphorus	0.096

LATENT HEAT OF WATER VAPOR (*Regnault.*)

Temperature C°.	*Total Heat.*	*Pressure* (*in pds. per sq. in.*)
0°	606.5	0.085
10	609.5	0.173
20	612.6	0.333
30	615.7	0.607
40	618.7	1.06
50	621.7	1.78
60	624.8	2.88
70	627.8	4.51
80	630.9	6.86
90	633.9	10.16
100	637.0	14.70
110	640.0	20.80
120	643.1	28.83
130	646.1	39.25
140	649.2	52.52
150	652.2	69.21
160	655.3	89.86
170	658.3	115.1
180	661.4	145.8
190	664.4	182.4
200	667.5	225.9

SPECIFIC HEAT.

	Between 0° and 100° C.	Between 0° and 300° C.
Iron	0.1098	0.1218
Mercury	0.0330	0.0350
Lime	0.0927	0.1015
Antimony	0.0507	0.0549
Silver	0.0557	0.0611
Copper	0.0949	0.1013
Platinum	0.0355	0.0355
Glass	0.1770	0.1990

Gases at Pressure of 1 Atm.	
Hydrogen	3.409
Air	0.238
Carbonic Oxide	.0.245
Steam	0.480

TABLE SHOWING THE INFLUENCE OF CONDITION, OR STATE, ON SPECIFIC HEAT.

	Solid.	Liquid.	Gaseous.
Water	0.5040	1.0000	0.4805
Bromine	0.0833	0.1060	0.0555
Tin	0.0562	0.0637	
Iodine	0.0541	0.1082	
Lead	0.0314	0.0402	
Alcohol		0.5475	0.4534
Bisulphide of Carbon		0.2352	0.1569

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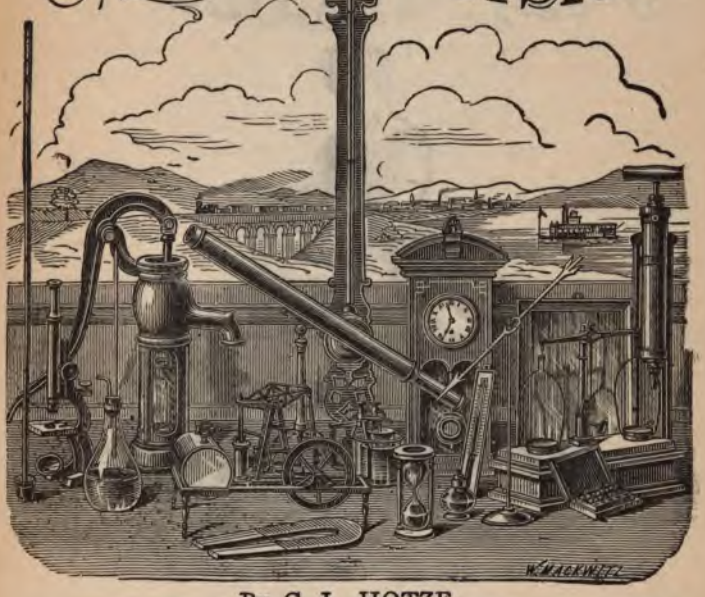

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